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ORIGINAL ARTICLES.

I.—Lamarck and Playfair: A Geological Retrospect of the Year 1802.[1]

By Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec. R.S., President of the Geological Society.

When the "Alliance Française" did me the honour of inviting me to give an address on this interesting occasion, the choice of an appropriate subject of discourse presented at first some little difficulty. On the one hand, as a representative of science in the "Alliance Franco-Britannique," it appeared to be incumbent upon me to choose some topic of a scientific kind, and by preference one which would in some way link our two countries together in common bonds of association. On the other hand, it was obviously inadvisable that the theme should be of a technical character which would be little suited for a general audience. After some reflection I decided to present for your consideration a brief account of two remarkable volumes, both of which, dealing with geological questions, appeared in the year 1802, the one in Paris, the other in Edinburgh. Though the political sympathies which for so many generations had linked France and Scotland in a friendly alliance had fallen somewhat into abeyance by the beginning of last century, the two nations still continued to be drawn to each other in the realms of culture by a common ardour in the prosecution of science and philosophy, and by the mutual reaction which, in these great domains of human thought, they exerted on each other.

At the time which I have selected for review, the science of geology, though still in its infancy, had awakened widespread interest on both sides of the Channel. The French and English observers who pursued it kept themselves, for the most part, in touch with the progress of enquiry in both countries. Thus, it is pleasant to remember that Desmarest, one of the brightest lights in the history of French geology, though he had determined not to notice in his great "Géographie Physique" the work of living writers, departed from his rule in order to give his fellow-countrymen an

[1] An address delivered before the "Alliance Française" in the Sorbonne, Paris, on 26th February, 1906.

account of the important memoir in which the illustrious Scottish geologist, Hutton, had then recently published the first sketch of his "Theory of the Earth." On the other hand, Hutton, by the numerous references and citations in his writings, showed how closely he had studied and how generously he appreciated the publications of his French contemporaries.

Looking backward to the beginning of the nineteenth century, we see the European geologists of that time ranged in two opposite schools, which might be called hostile camps, that waged with each other an animated and prolonged warfare. Not until after the chief antagonists of that time had one by one passed away did the feud finally die out. On the one side, the crowded ranks of the Neptunists marched under a banner on which was boldly emblazoned the war-cry of "Water." These militant theorists maintained, as the cardinal article of their faith, that our globe was once surrounded with an universal ocean, from whose waters the oldest rocks of the terrestrial crust were successively deposited as chemical precipitates. They scouted the notion that the earth possessed a highly heated interior, and nicknamed as 'fire-philosophers' those who held such a belief. They contemptuously dismissed the idea that any of the rocks of the crust had been erupted from below in a molten condition. They accounted for volcanoes by boldly reviving the ancient hallucination that they were caused by the accidental ignition of subterranean beds of coal. Hence as, on that supposition, volcanic action could only have come into existence after vegetation had flourished for a long time upon the surface of the earth, so as to form there thick deposits of combustible materials, they affirmed that the appearance of volcanoes must be a comparatively late phenomenon in the history of our planet. They had not the least conception of any source of energy lodged in the interior of the earth. The broken and convoluted rocks of mountain-chains awakened in these men no doubt of the fundamental truth of their doctrine, for they complacently explained these stupendous structures as nothing more than the natural result of the dessication, fissuring, and subsidence of the universal aqueous deposits.

On the other side of the field of battle, the phalanx of the Plutonists or Vulcanists, less numerous but not less confident and strenuous, proudly brandished their flag which bore the watchword "Fire." With much more tolerance than was shown by their opponents, these combatants freely admitted that a large part of the earth's crust undoubtedly consists of materials that were laid down in the sea. But they contended that the subsequent uplifting of these materials into dry land and ranges of mountains arose from the expansive power of heat within the globe. Following Descartes and Leibnitz, they conceived that this intensely hot interior was the source whence many crystalline rocks had been forced upward into the cooler crust, and that from the same source the activity of modern volcanoes is still derived.

The dust and din of this warfare have long since subsided. Looking back from the point at which we have now arrived in the

onward march of science, we may well wonder that such a controversy should ever have arisen at all, or that having been started it should have been waged so keenly and for so long. We must remember, however, that in those days the range of actual definite knowledge in regard to geological processes was still comparatively narrow, while at the same time the natural tendency to speculation and theory could be indulged in without much hindrance from the control of ascertained fact. On both sides of the dispute, imagination played a not unimportant part in the theoretical views proposed; but in this respect the partizans of Water must be allowed to have stood pre-eminent. Their complacent defiance of the laws of physics and chemistry, imperfectly as these were appreciated a hundred years ago, is one of the most curious episodes in the history of geology. The advocates of Fire came much nearer to the truth as we now understand it, though they too were inclined to push their distinctive opinions somewhat further than the known facts warranted.

It was while this contest of the rival schools had reached its height that the two volumes to which I wish to ask your attention made their appearance. Between the respective writers of these books—Jean-Baptiste de Lamarck and John Playfair—some curious parallels may be remarked. They were both intended by their parents to become ecclesiastics, the one in the Roman Catholic Church of France, the other in the Protestant Kirk of Scotland, but both eventually drifted into the ranks of science. Neither of them was a professed geologist, but was engaged, during most of his career, in the prosecution and teaching of widely different branches of knowledge. Both of them had passed middle life before they appear to have given much thought to the problems of geology, and neither of them published any special work on the subject save the volume which appeared in 1802. Each was led by a different path into the geological field of observation and theory, and, so far as known, neither had any acquaintance with what the other was engaged upon. While they entered upon the consideration of the subject from opposite sides of enquiry, they both endeavoured to take a broad view of Nature in order to frame a connected scheme of geological philosophy. And lastly, both sought to establish what in the language of their day was called a "Theory of the Earth"—in other words, a systematic grouping and discussion of the various processes whereby geological changes are effected.

Among the recorded careers of men of science, none surely is more picturesque than that of Lamarck. Born in 1744, of an old but not opulent family long settled in Picardy, he was, as I have said, originally destined for the Church, but when a lad of no more than 17 the martial traditions of his race proved too strong to be fettered by ecclesiastical restraints, and on the death of his father he boldly set out to offer himself as a volunteer in the French Army, then at war in Germany. He arrived at the front on the eve of a battle, at which he next day so distinguished himself for his coolness and bravery that he was at once promoted on the field to be an officer. Owing, however, to an accident that happened to him not long after

the declaration of peace, he had to leave the Army. Already he had acquired a strong liking for botanical pursuits, and in spite of his struggle with poverty he was able to devote himself with so much ardour and success to these studies that before many years were passed he published, under Buffon's auspices, his "Flore Française," and was soon acclaimed as one of the most eminent botanists of his day. In watching the progress of his career we see how, through the terrors of the Revolution, he remained quietly at the post which he had obtained at the Jardin des Plantes; how he pleaded successfully for the adequate endowment and reorganisation of that institution and of the Muséum d'Histoire Naturelle; how at last when 50 years of age he was offered a Professorship at the Museum, not of botany, to which he had till then devoted his life, but of invertebrate zoology, which he had not specially studied; how, with a courage and self-reliance not less marked than he had shown on the battlefield, he accepted the appointment, and after middle life began to acquire and then to teach what was to him a new science; and how before the lapse of many years he made himself the most philosophical zoologist of his time, and the pioneer of the modern doctrine of biological evolution. Year after year he continued his indefatigable researches and issued his voluminous publications, until his eyesight gave way, and he spent the last ten years of his life in blindness. But even under this grievous infliction he refused to quit his task. Sustained by the devoted affection of his eldest daughter, to whom he dictated the concluding volume of his immortal "Animaux sans Vertèbres," he survived to reach the ripe age of 85.

During his studies as "Professor of zoology, of insects, worms, and microscopic animals," Lamarck perceived the importance of connecting his investigation of living forms with an examination of the extinct types preserved in the various formations of the earth's crust. He saw that the organic remains in the rocks not merely furnish materials for elucidating the structure and affinities of living animals, but supply data for the interpretation of the ancient history of the globe. So vigorously did he prosecute his researches and so deeply did he leave his mark on this great department of natural history, that he is now everywhere acknowledged to be not less entitled to the name of founder of Invertebrate Palæontology than his great contemporary Cuvier is to that of founder of the Vertebrate division of that science. It was doubtless in the course of his investigation of fossil organisms that Lamarck's attention became rivetted to the consideration of some of the more important problems in the domain of geology. That he had pondered long and profoundly over them and sought their solution by original methods of his own device was at last revealed to the world by his publication of a treatise to which he gave the name of "Hydrogéologie." This was a small volume of 268 pages which made its appearance at the beginning of the year 1802, eight years after his appointment as Professor at the Museum. It never reached a second edition; indeed, it would appear to have excited but little

interest among his contemporaries. His crude speculations in physics and chemistry were not unnaturally regarded as the aberrations of a genius of which no serious notice need be taken, and his geological observations, some of which were at least as original and singular, seem to have been thought worthy of no better treatment. He inveighed against the methods and conclusions of the physicists and chemists of his day, though he does not appear to have himself studied these sciences experimentally, but to have evolved his ideas regarding them out of his own fertile brain. He went so far in his opposition to the current beliefs as to declare that even although the whole world should accept them he would be content to remain the solitary disbeliever.[1] He would seem to have been as good as his word, and to have scouted modern physics and chemistry as long as he lived.

Yet in neglecting his little volume, his contemporaries and their successors failed to perceive that amidst all its strange conceptions it made some really valuable contributions to a sound theory of the earth. In judging it we must bear in mind the general ignorance then prevalent as to what are now seen to be most obvious and elemental facts about the history of our globe; likewise the baneful influence of the orthodox theological creed that only some 6,000 years had passed away since the creation of the universe. We should remember, too, that the internecine dispute between the Neptunists and the Plutonists had brought discredit on the study of geology, which was taunted as a mere field of strife and visionary speculation, wherein men were too often guided rather by their desire to uphold their own theories or damage those of their opponents than by the wish patiently to collect the facts that would ultimately establish the truth.

Lamarck belonged to neither of the hostile schools, and he makes no allusion to them in his treatise. It is refreshing to turn from the angry debates and trifling observations of the time to his calm philosophical pages, and to come into touch there with a great mind which contemplated Nature as a whole and sought after the true interpretation of her working. He was essentially a biologist, and he was led to enter the geological domain, not as a partizan of any of the theories of the day, but as an ardent enquirer into the history of life upon the earth. He appeared as a bold pioneer into the vast and still little known field of the geological past, and though, as was only natural and at the time hardly avoidable, he wandered from the track, he yet succeeded in opening up some pathways where no previous explorer had appeared, and in clearing and widening others that had already been partially trodden.

One fundamental truth was vividly realised and eloquently proclaimed by Lamarck. At a time when the orthodox six thousand years were still generally believed to limit the age of the earth, he had acquired a profound conviction of the high antiquity both of the globe itself as a planet, and of the plant and animal life that has flourished on its surface. Again and again in

[1] "Hydrogéologie," p. 167.

his "Hydrogéologie" he pauses to dwell on this great fact of terrestrial history. "To Nature," he remarks, "time is nothing and is never a difficulty. She always has it at her disposal as a means without limit for the accomplishment of the greatest as well as of the least of her labours" (p. 67). "From the evidence furnished by the earth's crust and by the mass of the mountains, the antiquity of this globe is seen to be so vast as to be absolutely beyond the power of man to appreciate" (p. 88). "Yet how much will this antiquity seem to increase in man's eyes when he shall have been able to form a true idea of the origin of living bodies, as well as of the gradual development and perfection of these bodies; and, above all, when he shall recognise that lapse of time and the necessary conditions having been required to bring into existence all the living species which are now to be seen, he is himself the final result and present maximum of this development, of which the ultimate limit, if such should exist, can never be known" (p. 89).

Another essential principle of geology was recognised by Lamarck perhaps more clearly than by any of his predecessors since the time of Aristotle—the principle of constant change upon the surface of the earth. The limited range of knowledge then available on this subject prevented him, indeed, from forming any adequate conception of one great side of it. He did not recognise that besides the various agents that take their origin and do their work on the surface of the earth, there is another powerful source of energy lodged within the interior and manifesting itself from time to time by slow or by sudden movements that more or less change the face of the globe. He writes, indeed, of local catastrophes and of the elevations, subsidences, and heapings-up of material which may now and then result from volcanoes and earthquakes (pp. 83, 97), but that he could have had no adequate conception of the probable condition of the earth's interior and of its reaction on the surface may be inferred from his still accepting the ancient error that all volcanoes on the earth derive their heat and energy from the combustion of seams of coal and other inflammable materials buried within the crust of the earth (p. 111). Nor does he appear to have had any notion of the natural operations whereby land is elevated and mountain-chains are upheaved, for he explained these phenomena by a hypothesis which was hardly less extravagant than some of his speculations in physics and chemistry. Thus he held that the ocean-basins have been scoured out of the surface of the globe by the erosive action of the sea, which, in virtue of its tidal oscillation and westward movement, attacks the eastern coasts of the continents, and throws up its detritus on their western shores. He thought that in this way the vast hollow that holds the oceanic waters actually travels round the globe, and has done so completely more than once in the earth's history, each revolution requiring a period of nine hundred millions of years for its accomplishment (pp. 178, 266).

When he contemplated the progress of the changes that take place upon the surface of the earth Lamarck stood on firmer ground, for he drew his conclusions more from the facts of observation than

from the fancies of untenable theory. In his survey of these superficial changes he was more particularly struck by the far-reaching importance of those which result from the universal decay of the surface of the land and the removal of the disintegrated material to the bed of the sea. This impressive department of geological science had attracted attention from an early period, and had been especially studied by more than one observer during Lamarck's lifetime. His great contemporary Hutton, for example, had made it a cardinal feature in the scheme of his theory of the earth. The French naturalist, however, though he was probably indebted to the work of his predecessors, appears to have acquired a more vivid appreciation than any of them of the several processes that contribute towards the universal degradation of the dry land. He perceived that nothing in Nature can ultimately resist the various atmospheric influences which are ceaselessly at work upon every portion of the earth's surface exposed to their attacks. But in his little treatise he does not dwell on this part of his subject, contenting himself with a brief enumeration of these influences, in which he clearly distinguishes the effect of alternate wetness and dryness, of heat and cold, and more particularly of frost. The general effect of the combined operation of these subaerial agencies is pronounced by him to be the ultimate destruction of every aggregation of mineral matter, although the rate of advance of this disintegration must greatly vary, according to the nature and condition of the materials on which it acts (pp. 10, 11).

In one important respect Lamarck's outlook upon Nature differed from that of any previous or contemporary observer who occupied himself in the study of geological processes. Before his time it was the inorganic series of these processes which almost exclusively received attention. But Lamarck was led to contemplate the whole subject from the biological side. His long years spent in the investigation of plants and his subsequent absorbing researches in the animal kingdom had profoundly impressed him with the importance of what he called the 'Pouvoir de la Vie'—the power of living organisms to build up substances and structures which could have arisen through the operation of no inorganic agents. He had already, in some of his published memoirs, called attention to this great subject and formulated some of the conclusions to which he had been led, and he now devoted to its discussion the longest chapter of his little geological treatise. To him the processes of life formed one of the grand elemental forces of Nature, independent of but co-operating with the various physical agencies in building up the materials of the terrestrial crust, and in effecting the constant decay and reconstruction of the surface of the earth. It is only of late years that the efficacy of plant and animal life, as a department of dynamical geology, has been generally recognised, although we are still far from having discovered all the various ways in which organic bodies, living and dead, produce changes in the mineral kingdom.

There can be no doubt that in this matter Lamarck realised far more clearly than had ever been done before that the organic world

plays an important part among the geological operations which change the surface of the earth. Had he been content to state in explicit terms the facts of observation on which he relied, and to put forward tentatively, or at least less dogmatically, the conclusions which he drew from them, his views would not improbably have received the attention to which they would then have been justly entitled. But he submitted no evidence in support of his confident asseverations. He made statements as if they expressed admitted truths, when in reality they were for the most part either disputable or actually contrary to already ascertained fact. On such an unreliable basis his characteristic ardour led him to build a stupendous speculation, in the promulgation of which, besides giving flight to his winged imagination, he was able at the same time to proclaim his own peculiar chemical views and to express once more his scornful dissent from the prevailing chemistry of his day. It can hardly be matter for surprise that, as he himself complained, his opinions on these matters met with no serious attention.

It is interesting to trace the logical process by which so gifted a genius arrived at conclusions to which his contemporaries would pay no heed, and which his successors have consigned to oblivion. The external crust of the earth, which, in his opinion, might be three or four leagues in thickness, consists of various minerals and rocks almost wholly made up of compound substances. The materials of this crust have undoubtedly been exposed to the manifold agents of geological change, ever since the world began. According to the prevalent opinion in his time (an opinion which has been amply sustained by subsequent research) the elements have a natural tendency to enter into combination, and the general compound nature of the constituents of the crust could be cited in favour of the orthodox view. Lamarck, however, had formed a totally different judgment of the matter. His own investigations had led him to conclude that, owing to the operation of the agents of destruction, the tendency in Nature was in exactly the opposite direction, that is, towards the breaking up and simplification rather than to the formation of compound substances. He regarded the surface of the globe as a vast field whereon Nature is ceaselessly at work in destroying every compound and resolving it into its integral constituents. Not that this change is always effected at once, by a complete liberation of the components; it rather comes as the result of successive alteration, the cumulative effect of which is to leave the substances progressively less complex (p. 101). This process of disintegration appeared to him to arise sometimes from an inherent tendency in the material itself to split up into its component ingredients, but more frequently from the action of external provocative influences, such as those of heat, water, and saline solutions.

But if such be the normal order of things, how comes it, he asks, that the outer crust of our planet, which, for such a prolonged succession of ages, has been ceaselessly exposed to this destruction and simplification of composite bodies, should nevertheless now

consist of substances which are almost entirely compounds? With the confident anticipation that how much soever his contemporaries and their successors might retard the recognition of what he felt assured was a great discovery made by himself, Lamarck announced that there must exist in Nature a certain powerful and ever active cause which, while it counteracts the natural tendency of compound substances to break up into their constituent parts, is ceaselessly at work on its own side in forming new combinations. He triumphantly declared that this potent cause can be none other than the organic action of plant and animal life. Maintaining that the elements could never of themselves have formed the host of compound bodies on the face and within the crust of the globe, he went on to assert that without the operation of life, the 'Pouvoir de la Vie,' not one of these compound bodies could ever have come into existence (p. 106). Not only did he affirm that by the immediate action of vegetation, carbon, bitumen, coal, alumina, potass, clays, iron, and other mineral substances are formed, and that the action of animals gives rise to calcareous material, phosphates, sulphur, nitre, and other compounds (pp. 111, 118, 141, 153), but he claimed that, without exception, all the compound substances in the inorganic world, minerals and rocks alike, are nothing but the remains and débris of once living bodies (p. 115).

Protrusions of igneous matter into the terrestrial crust have thus no place in his system. Yet although he believed all amorphous rocks to have been accumulated under water he rejected Werner's doctrine of an universal ocean. The origin of granite, for instance, he explained by a complicated process wherein the essential molecules of the several minerals that constitute the rock are first disintegrated by the action of organisms; these molecules are then transported from the land by rivers into the sea, where they are deposited and come together to form the aggregate granite mass (pp. 142–145). So far from looking upon the granitic core of a mountain-chain as a plutonic intrusion from an inner magma, he regarded it as evidence of the site of a former river-current, by which its materials were built up on the sea-floor during the retreat of the oceanic waters, and the consequent emergence of the western shores of the land (pp. 145–149). As some rivers flow in tolerably straight courses for hundreds of miles, he could see no reason why, as the sea retired, they should not have accumulated granitic ridges as long as the longest crystalline core now to be seen in any mountain-chain. Obviously not even the wildest hypothesis of the Freiberg School was more completely a child of the imagination than this extraordinary speculation of the illustrious biologist of Paris.[1]

[1] His speculations on this subject, however, were not all original on the part of Lamarck. Cuvier, in his "Discours sur les Révolutions de la Surface du Globe" (3rd ed., 1825, p. 24), alludes to their prevalence, especially in Germany, at least as far back as the beginning of the nineteenth century, and to their recent development by his French contemporary in the "Hydrogéologie" and "Philosophie Zoologique."

(*To be concluded in our next number.*)

II. — Notes on the Corries of the Comeragh Mountains, Co. Waterford.

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XIII.)

THE corries and tarns of the Comeragh Mountains have received but scanty attention at the hands of geologists. In the Memoir of the Geological Survey [1] dealing with this portion of co. Waterford their position and height are mentioned, and reference is made to some of the glacial phenomena in their immediate neighbourhood, but no connected description of the whole group of corries is given. Kinahan, in his "Geology of Ireland" (1878), pp. 245, 310, refers briefly to them, and inclines to the view that they were cut out by the action of the sea on the flanks of the mountains, but that the rock-basins which they frequently contain were excavated by small glaciers. The position of the corries, chiefly on the north and east sides of these mountains, as elsewhere in Ireland, is attributed by him to the preservative action of the ice and snow, which would not melt in them so rapidly (owing to their colder aspect) as on the southern and western slopes, where the corries have been obliterated by denudation effected by ordinary subaerial agents. Carvill Lewis [2] refers to the glaciation of the Comeragh Mountains in several places, remarking that they "show signs of glaciation on their north-east side as high as 1,000 feet, up to which height they are rounded off and drift occurs. Above this they are jagged and contain cwms, glacial lakes, and other evidences of small local glaciers."

The following notes on these interesting corries must be considered to be only of a preliminary nature; a bathymetrical survey of the lakes themselves is necessary to complete their investigation, but possibly this may not be carried out for years owing to the absence of boats on their surface or in the neighbourhood and the difficulty and expense in conveying one to them.

Geological Structure of the District.

The mountains are entirely composed of Old Red Sandstone forming a wide flattened arch, or rather dome, of which the beds dip to the north and south respectively into the valleys of the Suir and Dungarvan, while to the west they dip at very low angles so as ultimately to pass under the Carboniferous Limestone in the district of Ballymacarbery. But this uniformity of structure is modified to some extent by small local folds and disturbances in the beds, the axes of which mostly trend east and west in accordance with the general system of folds affecting the Upper Palæozoic rocks of this part of Ireland. The eastern portion of the dome has been removed by denudation, exposing at the foot of the escarpment thus formed the much-worn platform of Ordovician rocks, on which the Old Red Sandstone rests with a very strong unconformity.

The Old Red Sandstone in the Comeraghs is estimated [3] to reach

[1] Mem. Geol. Surv. Ireland, Explan. Sheets 167, 168, etc., 1865, pp. 6, 7, 80.

[2] Carvill Lewis: "The Glacial Geology of Great Britain and Ireland," 1894, pp. 103, 133, 164.

[3] Mem. Geol. Surv. Ireland, Explan. Sheets 167, 168, etc., p. 14.

a total thickness of 3,200 feet, and consists of a locally developed basal breccia followed by about 1,000 feet of brownish-red conglomerate of various degrees of coarseness; and this is succeeded by reddish-brown shales, sandstones, grits, and strong conglomerates, with many white quartz pebbles, reaching a thickness of about 2,200 feet.

The jointing of the Old Red Sandstone rocks, both conglomerates and sandstones, is strikingly complete and well developed[1]; and the presence of these divisional planes and lines of weakness has an intimate connection with the production and preservation of the precipitous walls of the corries. The alternation of hard and soft beds of rock is clearly brought out by weathering in the cliff-faces of some of the latter, such as Coumshingaun, and results in the formation of successive small vertical cliffs or scars alternating with benches and talus slopes, expressing the vertical heterogeneity in the profile.

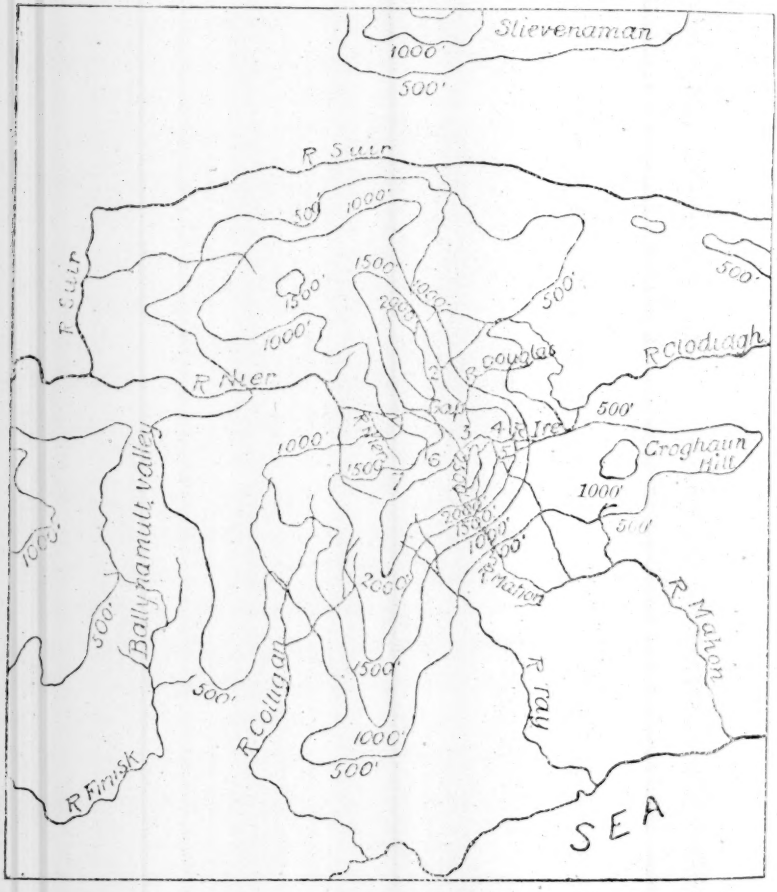
Orography of the District.

The Comeragh Mountains form a mass of high ground at the western end of co. Waterford, their main axis running nearly north and south; they rise to a maximum height of 2,597 feet above sea-level, and break off suddenly towards the east in a more or less regular escarpment, the summit of which is in most places over 2,000 feet high, but it sinks down gradually and loses its character to the north and south. The northern part of the range is sometimes known as the Reeks of Glenpatrick, and joins on to the line of lower rounded hills bordering the south side of the River Suir. The platform of older rocks which stretches away to the east with a gently undulating surface from the foot of the mountains is known as the plateau of Rathgormuck, and has an altitude of only 300–500 feet above the sea. On the west side the whole mass of the Comeragh Mountains is separated from the Knockmealdown Mountains by the long pass or valley of Ballynamult, which runs southward from the valley of the Suir. Behind the escarpment the Comeragh Mountains are deeply trenched by the valley of the Nier, which runs in a westerly direction so as almost to bisect them. This river, which ultimately joins the Suir just east of Newcastle, drains the greater portion of the western slopes and receives several tributary streams, some of which flow down from the cirque-headed valleys on its south side. The northern flanks of the mountains shed a few short unimportant streams direct into the Suir; and the south-west slopes are drained by the Colligan, which flows south into the sea at Dungarvan. The eastern escarpment, traced from its northern end, runs at first south-east at the foot of the Reeks, but at a point just south of Knockanaffrin Mountain it turns to the east, and continues in this direction for over one mile, forming a large embayment, at the bend of which is the important gap and pass into the head of the Nier Valley. This pass makes a conspicuous dip in the fairly uniform summit-line of the mountains, being only 1,500 feet above

[1] Haughton, "On the Physical Structure of the O.R.S. of Co. Waterford": Trans. Roy. Soc. Dublin, 1858, pp. 333–348.

sea-level, while on each side of it the top of the escarpment is over 2,000 feet high. A little north of Coumshingaun the escarpment again bends round and runs south for nearly three miles to the Mahon River.

In addition to the short, steep, grassy spurs which slope down from the face of the escarpment to the plain, and between which lie the rock-walled corries, there is an extensive promontory of hilly ground, composed of Old Red Sandstone and connected with the main mass by a low isthmus; it projects eastwards nearly opposite Coumshingaun for a distance of about four miles across the Lower Palæozoic platform, and rises towards its extremity into the prominent



Reduced to a scale 5 miles to 1 inch.

Fig. 1.—Contour-Map of the Comeragh Mountains and neighbourhood.

1, Lough More; 2, Coumduala Lough; 3, Coumgorra Loughs; 4, Crotty's Lough; 5, Coumshingaun Lough; 6, Comeragh Loughs; 7, Coumstilloge Loughs.

elevation known as Croghaun Hill, nearly 1,300 feet high. The eastern face of the Comeraghs is drained by many small streams, some of which are supplied by the tarns in the corries. North of the Croghaun spur these streams flow in a general eastward direction into the Clodiagh, which falls into the Suir, but south of Croghaun the streams run south-east to form the rivers Mahon and Tay, which enter the sea at Bonmahon and Stradbally respectively.

From the above description of the waterways it is seen that the Comeraghs give rise to a complete and independent drainage system on all sides, and form a local centre, as they are supposed to have done for the ice during the later stages of the Glacial Period.[1]

Distribution and Characters of the Corries and Tarns.

The corries in the Comeraghs fall into two groups, one of which lies along the steep eastern face of the mountains and the other along the south side of the Nier valley. In the former group they have mostly the character of mere niches in the escarpment, while in the latter group they attain nearly the dignity of short valleys. All are alike characterised by steep mural precipices and by their floor lying at some height above that of the thalweg of the main valley or the base of the escarpment, so that they possess the appearance of 'hanging valleys.' In the eastern series of corries not all have received names; only those which contain lakes are marked on the map with separate designations, but there exist several others which deserve notice.

We may first enumerate those which contain lakes, commencing at the northern end, and then proceed to describe them all in detail.

I (a). *Corries and their lakes in the Reeks of Glenpatrick.*

1. Lough More.
2. Coumduala Lough.

(b). *South of the great embayment.*

3. Coumgorra Lough.
4. Crotty's Lough.
5. Coumshingaun Lough.

II (c). *Corries and their lakes on the south side of the Nier Valley.*

6. Comeragh Loughs.
7. Coumstilloge Loughs.

The Reeks of Glenpatrick have only two corries occupied by lakes on their eastern face, but there are several other corries on the escarpment, the floors of which are occupied with great sloping heaps of talus from the cliffs above. A lake may have previously existed in them, but has been overwhelmed and filled up by the accumulation of this débris. In one case the absence of a barrier of moraine or scree material across the mouth, such as is found in all the others which hold a tarn, may account for this deficiency.

[1] Mem. Geol. Surv. Ireland, Explan. Sheets 167, 168, etc., p. 80. Kinahan: Geol. of Ireland, p. 245. Hull: Phys. Geol. Geogr. Ireland, 1878, pp. 103, 263.

There is one such lakeless corrie on the north of Knockanaffrin, and like all the corries on the Reeks it is shallow and wide-mouthed, consisting simply of a slightly curved amphitheatre of cliffs descending precipitously to a gently inclined floor, which from the mouth slopes more steeply to the plain below. The small streams which issue from these tarnless corries north of Knockanaffrin run down over the surface of the ground in shallow channels to join the Glasha River, which enters the Suir near Gurteen.

The two lakes, known as *Lough More* and *Coumduala Lough*, lie under the higher part of the escarpment, the former on the north side of Knockanaffrin and the latter on the south side. The altitude of *Lough More* is 1,518 feet, and it is situated in a wide, shallow alcove with the cliffs rising 550 feet above it. In size it only measures about 200 yards in length, and the stream issuing from it runs down to join the Clodiagh. A dam of morainic material rises about 60 feet above the water's level and holds up the lake.

Scale 3 4 inches to 1 mile.

Fig. 2.—Sketch-map of Coumgorra. Fig. 3.—Sketch-map of Crotty's Lough Corrie.

Coumduala Lough lies at an altitude of 1,533 feet in a shallow amphitheatre where the escarpment is nearly 2,100 feet high; screes cover the foot of the cliffs, and the lake, which is held up by a dam on the north-east, has its length (250 yards) parallel to the trend of the escarpment, and therefore across the mouth of the corrie. Its overflow is conducted down to the Clodiagh by a stream from its south-east corner.

From Knockanaffrin the escarpment decreases in height towards the Gap and curves round in an irregular semicircular line of cliffs and scars so as to form a large broken corrie, but without any definite floor, as the slope at the base of the cliffs is covered with talus and morainic heaps. One of the head-streams of the Clodiagh arises in this amphitheatre.

None of the foregoing corries or tarns are comparable in importance to the large ones south of the Gap which have now to be described,

and comprise those known as *Coumgorra, Crotty's Lough,* and *Coumshingaun.* All these contain lakes, and are situated close together. Thus, Coumgorra is only 500 yards distant from Crotty's Lough on the northward-facing part of the escarpment; and Coumshingaun, which looks west, lies only 650 yards south of Crotty's, while the divide separating the head of Coumgorra from Coumshingaun is not much over 700 yards wide. This triangular group of corries affords the most striking features of their class, and therefore merits special attention.

The corrie nearest the Gap is known as *Coumgorra*, and contains three lakes at successive levels; the two lower ones are merely expansions of the stream behind and between heaps of morainic material. This stream, which connects the three lakes, flows from

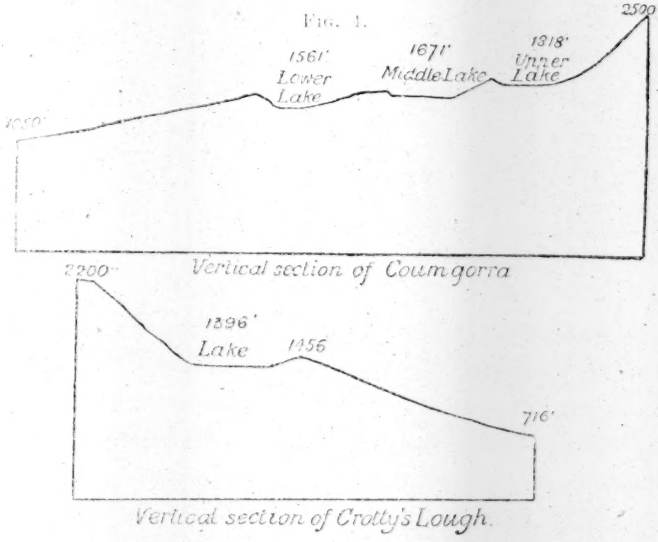


Fig. 5.

Vertical scale: 2,000 feet to 1 inch.
Horizontal scale: 1,760 feet to 1 inch.

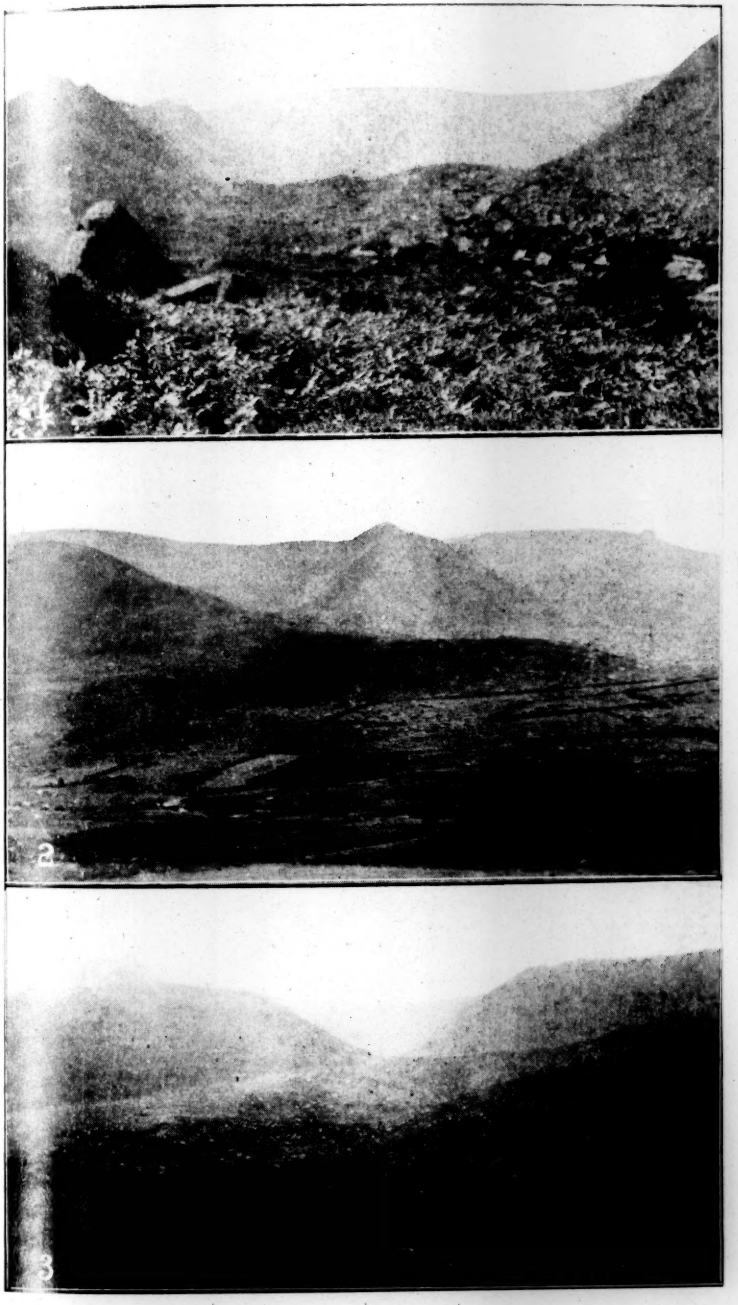
the mouth of the corrie in a north-easterly direction as the River Douglas to join the Clodiagh at Ross Bridge. The corrie itself is of large size, and opens northwards; it has an irregular shape, and on investigation is found to be composed of two contiguous and partly confluent amphitheatres, a weathered and semi-detached pinnacle of rock marking the point of intersection of the two curved lines of cliffs. The outer amphitheatre forms the western side of this composite corrie and is not deeply cut back, but the cliffs encircling it are higher and more precipitous, rising about 1,000 feet above their talus-strewn base, and more than 2,500 feet above sea-level. The two lower lakes lie in this outer corrie, but not close under its cliffs nor at the same level. Their origin is obvious,

the stream from the uppermost and inner lake having expanded into irregular small sheets of water in its attempts to escape between the confused mounds of moraine which obstructed its direct course, and through which it has not yet been able to establish a regular curve of erosion by cutting out a channel for itself. The inner corrie of Coumgorra faces north-west, and is likewise surrounded by bare craggy precipices with a fairly even skyline; the tarn lies at a height of 1,818 feet above the sea, and the mountain behind it has an altitude of over 2,400 feet.

This tarn—Coumgorra Lough proper—measures about 180 yards long by 120 yards wide, and is held up by a regular grass-covered bank of morainic material with such a straight course and even top as to present a most artificial appearance. The water escapes from the lake underground at the western corner, percolating through the loose material of the dam and flowing thence down to the middle lake. This lakelet lies at a level of 1,671 feet between somewhat irregularly disposed morainic mounds, which do not unite to form a single dam. The lowest lake lies about 100 feet lower down, and is of the same nature and origin; the mounds which hold the water back rise 50–100 feet above its level, and rest on the corrie-floor at its very mouth. Beyond and outside them the steeper slopes of the mountain descend at once for a continuous 500–600 feet till we reach another more or less level platform or broad shelf, formed by another but more evenly distributed mass of moraine, extending outwards in a roughly crescentic fashion for some distance over the plain, at the base to which it descends by a short steep face. Original irregularity of accumulation and subsequent denudation have obscured to some extent the outlines of this lower moraine, but its main features can be distinctly traced. There is nothing to indicate the existence of a rock-basin in the case of any of these Coumgorra tarns, and the stream from them runs either over or through morainic material in each case. The small erosive power of the stream, owing to the pure nature of its water, is noticeable. The moraines have the usual character of those of valley glaciers, and the large proportion of big angular blocks in their composition and on their uneven and scantily-clad surface gives the ground which they cover a wild and rugged appearance.

In size the composite corrie of Coumgorra measures about 1,100 yards from its mouth to its head, and has a width across its entrance of rather over 900 yards.

The next corrie to the east is that containing *Crotty's Lough*, which is an irregularly-shaped piece of water with its longest axis measuring about 350 yards and lying transverse to the mouth of the corrie. The level of the tarn is marked as 1,396 feet above the sea. The corrie faces north-east, and is formed by lofty cliffs on the west, south, and east sides. On the western side the precipice is vertical for several hundred feet in its upper part, and its top is over 1,000 feet above the water's edge. Steep grass-clad screes slope three-quarters of the way up the face of the cliffs at the head of the lake; and at the south-east corner two prominent bare rocky crags



Corries in the Comeragh Mountains.

rise up above the general rim of cliffs, one of which contains Crotty's Cave, and is a landmark for many miles. The eastern side of the corrie is mostly formed by a less precipitous spur from the mountain-side. The mouth is partially blocked by a conspicuous rounded hill strewn with large boulders and rising about 100 feet above the level of the water. On its outer or northern side this hill descends steeply for about 450 feet to a broad, roughly semicircular shelf with fairly level surface, probably representing an old moraine. The latter has an abrupt edge which slopes down suddenly to the plain about 300 feet below.

On each side of the rounded hill at the mouth of the corrie there is a possible outlet for the waters of the lake; the one on the north-west side would be over solid rock, and a rise of five or six feet in the level of the water would cause the outflow to be by this channel. On the other or eastern side the rounded hill is joined to the mountain spur by a ridge of morainic material which blocks up the wider and more natural outlet, and the lake discharges itself at this point by the water percolating through the dam and issuing on its further side in a series of springs which feed the swamps and give rise to the streamlet running down a depression in a north-easterly direction. It is noticeable that the rocky lip of the lake on the west is lower than the top of the dam on the east, but the outflow of the lake is nevertheless at a lower level on the other side of the median hill, which indeed appears to consist entirely of morainic material and to represent merely an unusually large and regular morainic mound. No solid rock is visible in its composition above the level of the lake, and there is no direct evidence that we have to deal with a true rock-basin in this instance.

(*To be continued.*)

III.—The Geological History of South Africa.[1]

By Dr. F. H. Hatch, F.G.S., M.I.C.E.,
President of the Geological Society of South Africa.

(*Concluded from the March Number, p.* 104.)

3. *Geological History of the Rocks.*

AFTER the granites, gneisses, schists, and sediments which make up the Swaziland System had been elevated to form a continental area extending over the northern and western portions of South Africa, denudation began, and the material thus produced was carried to the sea to form the Witwatersrand Beds. The nature of these sediments — they consist of conglomerates, grits, and shales— indicates a marine period with shallow-water conditions, which continued almost uninterruptedly during their deposition. They were accumulated first on a sinking, and then on a rising sea bottom, for the lower beds are composed largely of mud and fine sand, conglomerates only becoming abundant in the upper beds, which were formed in the later portion of the period when the

[1] Presidential Address delivered by Dr. F. H. Hatch to the Geological Society of South Africa, 29th January, 1906.

sea had become sufficiently shallow to allow of the accumulation of shingle and gravel. There is evidence in the Southern Transvaal that the land from which the sediments were mainly derived lay to the west, the sea to the east, for the lower Witwatersrand Beds, which consist solely of mudstones and fine sandstones in the east, gradually develop conglomerates with a decreasing amount of shale towards the west.

The northern shore-line of the Witwatersrand sea probably did not extend north of the 25th parallel of latitude, for in the Northern Transvaal we find the Waterberg Sandstone resting directly on the granites and gneisses of the Swaziland System, while in Southern Rhodesia, north of Bulawayo, the oldest deposits resting on these rocks are the Sijarira sandstones,[1] which immediately underlie the Matobola Coal-measures, in which fossils indicating a Permo-Carboniferous age have been found.

After the close of the Witwatersrand period, which was brought about by the final elevation of these beds above sea-level, they in their turn became exposed to the disintegrating forces of denudation, the resultant débris being transported and spread out by the heavy flood waters of torrential rivers, since we find the Ventersdorp period ushered in by the accumulation of coarse conglomerates and boulder beds, in which occur fragments of such characteristic beds of the preceding formation as Hospital Hill Slate and the auriferous conglomerates of the Upper Witwatersrand Series. This denudation produced the second break in the succession, marked as Unconformity No. II in the scheme given on page 98. The Ventersdorp period is particularly marked by volcanic manifestations, vast thicknesses of basic and acid lavas, volcanic breccia and tuffs having been accumulated, probably on a land surface.

Before the next submergence, that of the Potchefstroom period, the vast piles of volcanic accumulations, together with the boulder beds and coarse conglomerates of the Ventersdorp System, were long exposed to denudation, as there is a break (Unconformity No. III) between this and the succeeding system, the lowest member of which, the Black Reef Series, is found lying unconformably on every older formation down to the granite and schists of the Swaziland System. At some time before the deposition of the Black Reef and Dolomite Series, the Witwatersrand Beds had been subjected to a folding movement, as the latter are found bent into gentle synclines and anticlines, on the denuded remnants of which the former lie undisturbed.[2] The Potchefstroom System consists of three members: a small development of sandstone at the bottom with a basal conglomerate, dolomitic limestone and shales in the middle, and a great thickness of shales and sandstones on the top. This succession indicates a comparatively rapid submergence, continued until clear water conditions were reached, in which the accumulation of calcareous sediments became possible.

[1] A. J. C. Molyneux: Q.J.G.S., vol. lix (1903), p. 283.

[2] F. H. Hatch, "The Extension of the Witwatersrand Beds eastward under the Dolomite," etc.: loc. cit., p. 68.

The period during which the muds and sands now forming the Pretoria Series were deposited was probably one of slow oscillation between rising and sinking, the conditions representing on the whole a shallow-water phase. The shore-line of a bay-like portion of the sea in which the sediments of the Potchefstroom formation were deposited is well marked in the Transvaal by the outcrop of the Black Reef Quartzite, as may be seen by consulting a geological map of the Transvaal, but some allowance must of course be made for subsequent denudation, especially in the Lydenburg district. The main sea, however, extended over the southern portion of Bechuanaland and Griqualand, between the Vaal and Orange Rivers.

The final emergence of the rocks of the Potchefstroom System produced, by denudation, another great break in the succession, namely, the unconformity (No. IV) which separates the Waterberg from the Potchefstroom System. During the interval represented by this break, the beds of the latter were tilted, flexured, and dislocated. The resultant land surface furnished the material for the building up of the Waterberg formation. The basal conglomerates and breccias of the latter were first formed, namely, during the subsiding period. From the fact, to which attention has been drawn by Mr. Holmes, that pebbles of red felsite are found in these basal conglomerates,[1] it is probable that an eruption of acid lavas began while the Potchefstroom strata were being upraised; this igneous activity was probably long continued, for quite recently Mr. Mellor[2] has described in the lowest portion of the Waterberg Series at Rhenosterkop the occurrence of fragmental beds consisting for the most part of igneous material, from which he draws the conclusion that this period was marked by vigorous contemporaneous volcanic action, and he makes an interesting comparison with the conditions that obtained at the commencement of the Old Red Sandstone period in Scotland.

The character of the Waterberg rocks, consisting as they do largely of conglomerates, grits, and coarse sandstones, indicates shallow-water conditions in a slowly subsiding area. The constant occurrence of false bedding points to rapid sedimentation in shallow waters affected by strong and variable currents.[3] The pebbles of the basal conglomerate consist largely of quartzite derived from the Pretoria Beds, and there is evidence that the Waterberg sediments were deposited against an old land surface of the Pretoria rocks, which underwent denudation to supply the necessary material. The present distribution of the Pretoria Beds along the southern margin of the Waterberg Sandstone probably marks the shore-line of the sea or lake in which the latter was laid down. This sea extended over the greater part of the Northern

[1] G. G. Holmes, "Some Notes on the Geology of the Northern Transvaal": Trans. Geol. Soc. S. Afr., vol. vii (1904), pp. 55–56. "The Geology of a part of the Rustenburg District": Trans. Geol. Soc. S. Afr., vol. viii (1905), p. 6.

[2] E. T. Mellor, "Volcanic Action in the Waterberg Formation": Trans. Geol. Soc. S. Afr., vol. viii (1905), p. 38.

[3] E. T. Mellor: Transvaal Geol. Surv. Rep., 1903, p. 17.

Transvaal, and probably included a portion of Southern Rhodesia; it may have been landlocked, for the facts that the Waterberg formation has been found resting on an uneven floor, and that near the base very coarse irregular conglomerates [1] are met with, seem to militate against this formation being a true marine deposit.

The Cape Colony representative of the Waterberg Sandstone, namely, the Table Mountain Sandstone, also consists of sandstone, but with less conglomerate. Conglomerates, although scarce, however, do occur, and Rogers has described in the Pakhuis Pass, near Clanwilliam, the occurrence of ice-scratched pebbles which appear to have come from a glaciated region, and to have been carried to their present site by the agency of floating ice.[2] From an increase in the degree of coarseness of the sediments towards the west, and the greater frequency of conglomerates in the Piquetberg division and the Olifants River Mountains, Rogers argues that their source must have lain in that direction, and that the sediments were accumulated at no great distance and in shallow water. In his view the Table Mountain Sandstone is probably of fluviatile origin.[3]

The Table Mountain Sandstone is followed conformably at the Cape by the Bokkeveld Beds, the character of which points to a continuance of the subsiding phase. The fossil remains indicate marine conditions, although the frequent occurrence of false bedding in the sandstones precludes the possibility of very deep waters. The fossil fauna of the Bokkeveld Beds shows that they are homotaxial with the Devonian System, but whether Upper, Middle, or Lower has not yet been decided. The upper beds of the Bokkeveld and the succeeding Witteberg Beds indicate a change to lacustrine or fluviatile conditions, the beds consisting of mudstones and sandstones which, with the exception of a few plant remains, are barren of organisms. It is possible, as suggested by Mr. Rogers,[4] that at about the middle of the Bokkeveld period open communication with the sea may have been again cut off, deposition subsequently taking place by fluviatile agencies in inland seas. This would account for the absence of marine organisms in these beds. At the Cape the Witteberg Beds are followed without a break by the shales forming the lowest beds of the Dwyka Series. Northwards, however, the Witteberg and Bokkeveld Beds gradually thin out, and the Dwyka Series finally rests unconformably on the Table Mountain Sandstone. From this the deduction can be made that owing to the elevation of the beds above sea-level, they became subject to denudation before the commencement of the Dwyka epoch, and it is even possible that still further north denudation may have commenced before the Witteberg epoch, so that the latter series was never deposited in

[1] E. T. Mellor, "The Waterberg Sandstone Formation": Trans. Geol. Soc. S. Afr., vol. vii (1904), p. 40. Mr. Mellor instances the occurrence of boulders ranging up to 8 feet in diameter. These must have been transported by streams of a torrential character.

[2] A. W. Rogers, "The Glacial Conglomerate in the Table Mountain Series near Clanwilliam": Trans. S. Afr. Phil. Soc., vol. xvi (1905), p. 1.

[3] A. W. Rogers: "The Geology of South Africa," p. 395.

[4] "Geology of the Cape Colony," p. 396.

these northern regions; and in the Transvaal it is most likely that even the Bokkeveld Series was never represented. During the accumulation of the Dwyka Series the northern part of South Africa was covered with ice, for it is now generally admitted that the Dwyka Conglomerate has been formed of rock fragments, boulders, and mud, which have been carried towards their present site by glaciers moving from a northern mountainous country southward. That the highest portions of these mountains were probably situated in the Northern Transvaal somewhere about the present Waterberg district, is indicated by the distribution of the glacial conglomerate.

The Dwyka Series as well as the rest of the Karroo rocks appears to have accumulated in a great inland sea which occupied practically the whole of Central South Africa as at present constituted. The southern shore-line of this vast lake extended east and west along the northern margin of the present coast ranges of Southern Cape Colony. To the east it passed into the present Indian Ocean somewhere about the Gualana River, returning at Port St. John, whence it stretched north-eastward parallel to the present coast of Natal, the north-western boundary extending roughly along the present course of the Vaal River as far as Vereeniging. The fossil evidence points to fresh-water, or at least to brackish conditions, and the frequent occurrence of false bedding, ripple-marks, sun-cracks, worm burrows, etc., indicates that the water could not have been deep. The Dwyka Conglomerate was deposited partly in this lake by the agency of floating ice; partly it consists of ancient moraines the accumulation of which slowly followed the retreating ice northwards. In conformity with this twofold mode of origin, there are two facies of the Dwyka Series: a northern, lying unconformably on an uneven surface (often grooved and polished) of the older rocks, and a southern, resting conformably on the uppermost member of the Cape System. In the Transvaal the Dwyka covering has preserved interesting features of the pre-Karroo land surface. Thus Mr. Mellor[1] considers that the valleys of the Elands River, Bronkhorstspruit, and the Wilge River are of pre-Karroo origin. At the beginning of Karroo times they became filled with the conglomerate, and have in recent times been re-excavated. The coal deposits, which at Vereeniging and elsewhere in the Southern Transvaal and at Dundee and Newcastle in Natal are found in the Ecca Beds immediately above the Dwyka Conglomerate, show that a luxuriant tropical vegetation flourished in the Ecca epoch; while the fact, first pointed out by E. J. Dunn,[2] that seams of breccia of almost identical character with the Dwyka are interbedded with the coal at Vereeniging, seems to indicate that glaciers were still in existence while the coal beds were being deposited. Professor Edgeworth David[3] has described a similar occurrence in New South

[1] E. T. Mellor: Transvaal Geol. Surv. Rep., 1903, p. 20.

[2] E. J. Dunn, "Notes on the Dwyka Coal-measures": Trans. S. Afr. Phil. Soc., vol. xi (1900), p. 67.

[3] Edgeworth David, "Evidences of Glacial Action in Australia in Permo-Carboniferous Time": Q.J G.S., vol. lii (1896), p. 289.

Wales, where a group of Coal-measures over 230 feet thick and comprising from 20 to 40 feet of coal is sandwiched in between the erratic bearing horizon of the 'Lower Marine Series' and the similar horizon of the Upper Marine Series. There appears to be indicated in these facts a recurrence of a glacial epoch separated by a milder interglacial period. Professor Penck, however, to whom I showed specimens of these later breccias in borehole cores from the Vereeniging Coalfield, thought they probably represented a rewash or remanié of the true Dwyka. With regard to the age of the Transvaal coal, the occurrence of *Sigillaria Brardi* at Vereeniging supplies a link with Europe, and on this evidence Seward[1] assigns the beds to the Permo-Carboniferous period, and suggests that the commingling of *Sigillaria* species with the *Glossopteris* flora indicates an overlapping of two distinct botanical provinces.

A recurrence of the conditions suitable for the formation of coal deposits took place at a much later epoch in the Karroo period, namely, at the beginning of Stormberg times (Molteno Beds). Between the two horizons there are some 7,000 feet of strata in the geological column, 5,000 feet of which are made up of the Beaufort Series, which requires no special mention here, except for the abundant occurrence in it of the remarkable labyrinthodont and dinosaur remains. The bones of these animals must have been washed into the lake by rivers.

At the top of the Stormberg Series, and consequently occupying the highest position in the system, are the basic lavas and ash-beds of the Volcanic Group. The interstratification of ash-beds and lava-flows with sandstone points to some subaqueous eruption; but the bulk of the later flows were subaerial, and the accumulation of such a vast pile of volcanic material—it is some 4,000 feet thick—determined the watershed of the Drakensberg as it exists to-day in Basutoland and the Eastern Province of Cape Colony. Many of the vents by which the eruptions took place have been found,[2] cutting through the Cave Sandstone, by the Cape Geological Survey; but Mr. Schwarz is of the opinion that fissure eruption also played a part in the formation of the volcanic beds.

It is interesting to note that the remarkable series of lavas occupying the so-called Springbok Flats in the Transvaal, and known as the Bushveld Amygdaloid, has been found by the Transvaal Survey to overlie sandstones which are considered to be of Karroo age, and has been provisionally referred to the Stormberg epoch.[3] There is certainly a remarkable resemblance in the

[1] A. C. Seward: Q.J.G.S., 1897, p. 322.

[2] An interesting account of the geological history of these eruptions is given by Mr. du Toit in a paper on "The Forming of the Drakensberg": Trans. S. Afr. Phil. Soc., vol. xvi, pt. 1 (1905), p. 65. See also "Report on part of the Matatiele Division, with an Account of the Petrography of the Volcanic Rocks," by E. H. L. Schwarz: Geol. Comm. Rep. for 1902, p. 11; Capetown, 1903. Also "Geological Survey of Elliott and Xalanga," by A. L. du Toit: Geol. Comm. Rep. for 1903, p. 109; Cape Town, 1904.

[3] E. T. Mellor: Transvaal Geol. Surv. Rep., 1904, p. 31; Pretoria, 1905. Also Trans. Geol. Soc. S. Afr., vol. viii (1905), p. 37.

petrographical habit of these amygdaloids to the lavas of the Volcanic Group of the Drakensberg and Malutiberg. In this connection, the discovery by the Survey of a 'pipe amygdaloid' in the Bushveld lavas, similar to the characteristic rock of the Stormberg Volcanic Group, is noteworthy.

The dolerite intrusions, which are so widely distributed in the Karroo rocks, and form such a striking feature in their scenery, belong to a period somewhat posterior to the volcanic eruptions of the Stormberg epoch; their late limit is fixed by the fact that boulders of the typical dolerite have been found in the Umtamvuna (Upper Cretaceous) rocks of the Pondoland coast.[1] Intermediate in age between the Stormberg volcanoes and the period of intrusion of the Karroo dolerites, are the volcanic pipes so well known on account of the diamond being a constituent of their breccia filling at Kimberley and in the Transvaal. The facts on which this argument is based are as follows :—The Stormberg lavas are occasionally penetrated by dykes,[2] which probably belong to the Karroo dolerites, while Messrs. Rogers and Du Toit[3] have shown that the Sutherland pipes, which are analogous to the diamond-bearing deposits, except that they do not yield diamonds, are of later age than the latter.

The exact period at which the Cape Formation and the overlying Karroo Beds were folded to form the great mountain ranges of the Southern Cape (the Zwarteberg, Langeberg, etc.) cannot be fixed, but it was after the deposition of the Lower Karroo Beds, as these are involved in the folding, and before the deposition of the Uitenhage Beds, since the latter lie undisturbed on the folded Cape Formation.

To summarise: we have in South Africa evidence of the former existence of at least three periods during which the greater portion of South Africa was elevated above sea-level, besides the one we live in, which has endured since Karroo times. The first of these is indicated by the break in the succession below the Witwatersrand System; the second by the volcanic and fluviatile deposits of the Ventersdorp System, and the unconformity between the latter and the succeeding Potchefstroom System; and the third by the break between the Potchefstroom and the Waterberg Sandstone. Between these must have intervened three periods, during which a large portion of South Africa was submerged, and the marine and littoral sediments of the Witwatersrand, the Potchefstroom, and the Cape Systems were deposited; and a long period of fresh-water sedimentation during which the Karroo rocks were accumulated by the agency of vast river systems discharging into great lakes. The coastal deposits (the Uitenhage and Umtamvuna Series), which are marine deposits of a later (Cretaceous) period, are not considered here, as they play only an insignificant part in the geology of South Africa; and I have limited myself to the close of the Karroo period.

[1] Rogers & Schwarz: Ann. Rep. Geol. Comm., 1901, pp. 25–46; Capetown, 1902.

[2] A. C. du Toit, "The Forming of the Drakensberg": Trans. S. Afr. Phil. Soc., vol. xvi (1905), p. 67.

[3] Rogers & Du Toit, "The Sutherland Volcanic Pipes and their Relationship to other Vents in South Africa": Trans. S. Afr. Phil. Soc., vol. xv (1901), p. 61.

It is not likely that at any period since its first upheaval the whole of South Africa has been submerged; indeed, there is evidence that the northern region remained uncovered and subject to erosion up to the commencement of Karroo times. On the other hand, it is unlikely that the continent has always had its present limits; the similarity of the remarkable Damuda-Talchir flora of India, the Newcastle flora of Australia, and the Lower Karroo flora of South Africa indicates that in Permo-Carboniferous times South Africa was probably united to India and Australia to form one great continent, which Suess[1] has named Gondwanaland. Blanford[2] even suggests that in Mesozoic times South Africa was also connected with South America, so that "a girdle of land may have extended round nearly three-quarters of the earth's circumference," from Peru to New Zealand.

Volcanoes have played a great rôle in the geological history of South Africa, and the traces of this igneous activity survive in the form of lavas, with or without volcanic tuffs and breccias, or in the various forms of intrusive igneous material (laccolites, sills, dykes, etc.), or again as volcanic necks and 'pipes.' There are at least five distinct periods in which South Africa has been the theatre of intense igneous activity, and the ages of these may be arranged as follows: —

1. Between the close of the Witwatersrand and the commencement of the Potchefstroom periods, the period of the eruption of the Ventersdorp lavas, tuffs, and breccias.

2. A period commencing after the close of Potchefstroom, and extending into the early Waterberg times, in which the intrusion and eruption of the Red Granite and associated felsite took place.

3. At the close of the Stormberg epoch, eruption of the Stormberg lavas.

4. Between the close of the Karroo period and the commencement of the Umtamvuna (Upper Cretaceous) epoch, intrusion of the dolerite dykes and sills.

5. After the intrusion of the dolerites, formation of the pipe breccias.

With this summary I must bring my account of the geological history of South Africa to a close, although I have but touched the fringe of the subject. Much remains to be discovered before the secrets of the past can be completely deciphered, and it must be remembered that geology in South Africa is still young. It shows, however, a vigorous growth for all its youth, and I am convinced that in the next few years great progress and many new discoveries will be made. In this progress the Geological Society of South Africa will doubtless have a large share, and uphold or increase the high standing it has already won.

[1] "Das Antlitz der Erde," vol. i, p. 768; Vienna, 1885.
[2] W. T. Blanford: Presidential Address, Proc. Geol. Soc., vol. xlvi (1890), p. 106.

ORDER OF SUPERPOSITION OF THE STRATIFIED ROCKS OF SOUTH AFRICA.

European Equivalents.	Southern Cape Colony.			Transvaal.
Rhætic	Karroo System.	Stormberg	Volcanic Group. Cave Sandstone. Red Beds. Molteno Beds.	*Missing.*
Permo-Carboniferous		Beaufort		*Missing.*
		Ecca and Dwyka		= Ecca and Dwyka.
				~~ (Unconformity No. V.)
Devonian	Cape System.	Witteberg		*Missing.*
		Bokkeveld		*Missing.*
		Table Mountain Sandstone		= Waterberg Sandstone.
				~~ (Unconformity No. IV.)
			Potchefstroom System.	Pretoria Beds. Dolomite Series. Black Reef Series.
				~~ (Unconformity No. III.)
			Ventersdorp System.	Boulder Beds, Volcanic Breccias, Klipriversberg Amygdaloid, etc. Elsburg Conglomerates.
				~~ (Unconformity No. II.)
			Witwatersrand System.	Upper Witwatersrand Beds Lower Witwatersrand Beds.
				~~ (Unconformity No. I.)
Archæan.	Malmesbury Series.			= Swaziland System.

Note.—This slip is intended to correct the Table given in Dr. F. H. Hatch's Address, Part I, p. 98, in the March number, 1906, in which, by an error, the Devonian formation was made to embrace with a bracket *all* the older Transvaal rocks.—EDIT. GEOL. MAG.

IV.—Superheated Water.

By A. R. Hunt, F.L.S., F.G.S.

THE abstract in the Geological Magazine of Professor Beck's paper on ore veins and pegmatites is of great interest to myself, as it deals with two points which I pressed on geologists in 1894 and earlier, viz., the crystallisation of vein-minerals out of superheated water, and the doubtful origin of that water. The special difficulty is raised by the Dartmoor veins, as the water they contain, together with the granites, is sometimes salt and sometimes fresh, and is of all degrees of original supersaturation. I wrote as follows:

"The question as to the marine or plutonic origin of the brine-inclusions referred to is of transcendent importance in connection with the question as to whether the water ejected by volcanoes is of meteoric or marine origin, or derived from the interior magma" (Geol. Mag., 1894, p. 99).

Then, referring to the various theories current about the Dartmoor granite, I wrote:

"It would greatly facilitate further research in the Dartmoor area if the following three points could be definitely decided:—

"(1) Whether the volcanic hypothesis is tenable?

"(2) Whether the chlorides in the quartzes are of marine or plutonic derivation?

"(3) An explanation of the immediate juxtaposition of brine and fresh-water inclusions."

The latter are sometimes within $\frac{1}{2000}$ of an inch of each other. One of these pairs is figured and described on p. 102 of the paper referred to.

At the time I wrote, in 1894, I laboured under the extraordinary delusion that I had originated the idea of the marine origin of the brine locked up in veins and granites, having arrived at that conclusion entirely through the $\frac{1}{8}$ and $\frac{1}{16}$ objectives. I thought it a problem of micro-petrology solely. But Sir Henry de la Beche had actually before 1839 postulated the action of superheated salt water (i.e. "greatly heated water under pressure") in deep-seated and therefore "greatly heated" fissures in the earth's crust (Report Devon and Cornwall, p. 387). De la Beche's priority of suggestion I fully acknowledged in the Geological Magazine in 1901, in "The Age of the Earth and the Sodium of the Sea," but I never succeeded in making a single convert, and the late General MacMahon assured me with equal kindness and candour that he thought my theory unthinkable.

I should be well satisfied if I could only establish the first step, viz. the crystallisation of veins and pegmatites from superheated water, as I would trust all the rest to follow. According to Professor Beck this first step is allowed by such distinguished foreign observers as Messrs. Brögger, Rosenbusch, Arrhenius, Vogt, Grubermann, and others.

In 1889 I wrote that the "brine and salt crystals . . . tell us clearly enough that we have superheated water to deal with, and

water highly charged with salts; but water it is, and not gas . . . " (Trans. Dev. Assoc., 1889, p. 244).

Granted this first step, and I believe we shall ultimately reach the following conclusion, viz., that our planet consolidated first on the surface of the molten spheroid, in the form of a floating slag; that all the plutonic rocks, as we know them, are the result of the world-old conflict between the waters on the surface and the heat beneath the surface; and that all the water we see locked up in granites and schists, whether in the form of water or of hydrous minerals, came originally from above and not from below. It will no doubt be considered a very large order, but I believe there is a sufficient deposit in the bank of fact to meet the whole draft.

Perhaps, to make sure, I had better explain that by 'meteoric' water I only meant water derived from the atmosphere, as distinguished from water derived from the sea.

Professor Beck makes the important incidental remark that tourmaline is "the characteristic mineral of all pegmatites." Although, according to English textbooks, tourmaline is only an occasional constituent of English pegmatites, I wish that when it does therein occur it might be accepted as an original mineral, and not derived from mica. Certainly, if characteristic, it can scarcely be derived and secondary.

An interesting subject in connection with superheated water is the plutonic character of the changes so commonly observed in diabases. In the course of my examination of the Devonshire green schists I examined several of the most altered Devonian diabases, and was much interested to note that one not only met with very active bubbles in the secondary minerals, but also crystal deposits in the fluid inclusions, similar to those in granite, only not markedly cubic. Then in the green schists we find fluid inclusions in the secondary albite granules. To find what were once possibly volcanic tuffs exhibiting full plutonic characteristics was to myself interesting and unexpected; but when I brought this, to me, novel aspect of superheated water, under the description of hydrothermal metamorphosis, before the British Association at Belfast, a friend kindly informed me that the Committee of Section C did not consider my subject new.

Dr. Sorby, no doubt, referred to the inclusions in the quartzes of schists, both detrital grains and secondary, in his addresses to the Microscopical and Geological Societies, but I was quite unaware that any work had been done on the inclusions in the secondary quartzes and felspars of green schists and diabases. When one carefully explores one of these quartz grains in an altered diabase, under a high power and strong light, the phenomena seen are strikingly similar to the secondary quartzes seen in some plutonic felspars; both containing, as they sometimes do, belonites, active bubbles, and deposited crystals. Both results seem due to corrosion by superheated water charged with minerals and salts, followed by the crystallisation of fresh minerals out of such water.

Of course, in my own case, these have been only chance

observations incidental to other work, and I only wish I knew where the special subject has been studied and described. The hydrothermal phenomena of the Devonian diabases, of the Devonshire quartz- and mica-schists, and of the green rocks, and of the so-called pegmatite felspathic veins connected with the green rocks—these present to my mind the most interesting problems in the debatable Devonshire area, and, compared with them, the question as to whether the schists are Archæan or Devonian, or, as has recently been suggested, any possible age between those geological horizons, does not matter the toss up of a bad half-penny. Certainly, if neither Archæan nor Devonian I do not care what they are.

I may perhaps explain that I have never possessed a first-rate petrological microscope, and that for the work above referred to the small students' microscopes are about as useful as a pocket lens, as a mechanical stage and a somewhat elaborate achromatic condenser are as essential as are high-powered objectives. But the old microscopes with these fittings are lacking in other advantages. This fact, in addition to my not being well grounded in the identification of minerals, makes it impossible for me to attempt any difficult work myself, and that is really the reason why I have so often pressed these questions upon others, when every motive of self-interest would have bade me avoid unpopular doctrines and keep to the beaten track.

The motion of bubbles is the easiest proof of the presence of fluid. The following device, to induce a bubble to move, may not be known to all microscopists. If the substage condenser is furnished with a rotating diaphragm, to allow of oblique light from any point, such a diaphragm, if rotated under strong lamp light, will often make a bubble move owing to the heat thrown laterally upon the fluid inclusion.

Considering the attention paid to the subject of superheated water by Dr. Sorby and my eminent namesake, the late Dr. Sterry Hunt, more than a quarter of a century ago, it is most remarkable that the investigation has not been followed up with more vigour and determination by their successors. It is well worth conquering.

V.—The Pendleton Earth-shake of November 25th, 1905.

By Charles Davison, Sc.D., F.G.S.

PENDLETON lies on the north-west side of Manchester and within the borough of Salford, and is traversed by the well-known Pendleton or Irwell Valley fault, a fault which has been traced for more than twenty miles from the neighbourhood of Bolton to that of Poynton in Cheshire. The fault is still slowly growing, for, on February 10th, 1889, a slip near Bolton gave rise to an earthquake of intensity 6, felt over an area of about 2,500 square miles.[1] Small superficial movements may also be taking place close to

[1] Geol. Mag., Dec. III, Vol. VIII (1891), pp. 306–316.

Pendleton, though here probably aided by mining operations. Within the last seven years there have been local shakes on three occasions, namely, February 27th, 1899, April 7th, 1900, and November 25th, 1905. The materials for the study of the first two of these shakes are not quite sufficient to determine the boundaries of their disturbed areas with accuracy. The areas appear, however, to have been approximately circular in form and about four or five miles in diameter. In both cases the intensity of the shock was 4, or nearly 5. In 1899 the centre of the disturbed area was about half a mile north of Pendleton and a short distance on the north-east or downthrow side of the Pendleton fault; in 1900 it lay a mile or two farther to the south or south-south-east of the former centre.[1]

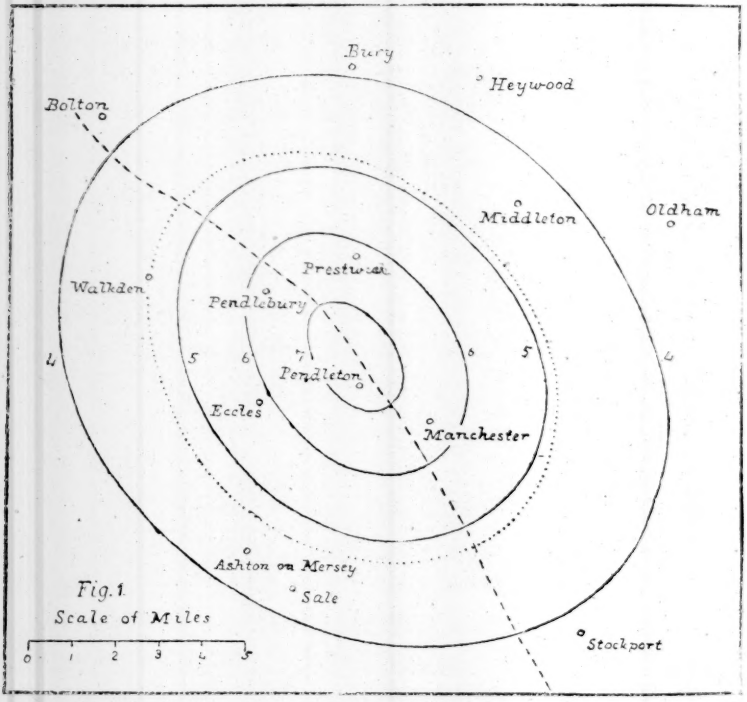


FIG. 1.—Isoseismal lines of Pendleton Earth-shake, Nov. 25th, 1905.

The earth-shake of November 25th, 1905, was strong enough to be noticed in many besides local newspapers, and was investigated without delay. The materials for its study are therefore abundant, the following account being based on 139 records from 45 places, and on negative records from 4 places.

[1] GEOL. MAG., Dec. IV, Vol. VII (1900), p. 175; Dec. IV, Vol. VIII (1901), p. 361.

The shock occurred at 3.42 a.m., the centre of the disturbed area being $\frac{3}{4}$ mile north of the centre of Pendleton (in lat. 53° 29·6′ N., long. 2° 15·8′ W.). At this place the intensity of the shock was 7, and not much below 8, for there was some slight damage done, several chimney-pots and one chimney-stack being thrown down. On the accompanying map (Fig. 1, which is bounded by the parallels of 53° 37′ and 53° 23′ N. lat. and by the meridians of 2° 4′ and 2° 29′ W. long.) four isoseismals are shown, corresponding to intensities 7 to 4. The isoseismal 7 is 3 miles long, $1\frac{3}{4}$ miles wide, and 4 square miles in area, but, towards the east, the curve may not be quite accurately drawn. The next isoseismal, of intensity 6, is 6 miles long, $4\frac{1}{2}$ miles wide, and contains 21 square miles; the isoseismal 5 is $9\frac{1}{2}$ miles long, $7\frac{1}{2}$ miles wide, and 56 square miles in area; while the isoseismal 4, which bounds the disturbed area, is $15\frac{1}{4}$ miles long, 12 miles wide, and includes an area of 144 square miles. The longer axes of the isoseismal lines are parallel or nearly so, and run from N. 37° W. to S. 37° E. The distances between the isoseismals are approximately the same on both sides of the longer axes.

The shock was brief in all parts of the disturbed area, the average of 11 estimates of the duration being $2\frac{1}{2}$ seconds. It consisted of a few prominent vibrations, quick-period tremors having been apparently absent.

The sound-area, which is bounded by the dotted line on the map, is $10\frac{3}{4}$ miles long, $8\frac{1}{4}$ miles wide, and contains 70 square miles. It includes the whole of the isoseismal 5, but falls short of the isoseismal 4 in all directions. The sound was heard by 75 per cent. of the observers. By 14 per cent. of these it was compared to passing traction engines, etc., by 13 per cent. to thunder, by 4 to wind, 9 to loads of stones falling, 31 to the fall of a heavy body, and by 29 per cent. to explosions; that is, 31 per cent. of the observers refer to types of long, and 69 to types of short, duration. The beginning of the sound preceded that of the shock in 49 per cent. of the records, coincided with it in 24, and followed it in 27, per cent.; while the end of the sound preceded that of the shock in 13 per cent. of the records, coincided with it in 16, and followed it in 71, per cent. The duration of the sound was greater than that of the shock in 87, and equal to it in 13, per cent. of the records.

In the rapid decline of intensity outwards from the epicentre, and in the nature of the sound-phenomena, the Pendleton earth-shake differs widely from other shocks in Great Britain.

(i) Decline of Intensity.—During the last seventeen years there have been eight British earthquakes of intensity 7 (and nearly 8), namely, the Inverness earthquakes of 1890 and 1901, the Pembroke earthquakes of 1892 and 1893, the Derby earthquakes of 1903 and 1904, the Carnarvon earthquake of 1903, and the Doncaster earthquake of 1905. In the following Table, the average areas contained by the different isoseismals are contrasted with the corresponding figures for the Pendleton earth-shake :—

Isoseismal.	Area in Square Miles.	
	Average of the above earthquakes.	Pendleton earth-shake.
7	500	4
6	2,500	21
5	8,300	56
4	22,000	144

(ii) Sound-Phenomena.—In earthquakes which disturb an area of not more than a few hundred square miles the average percentage of audibility is about 98, and the sound-area coincides with, or overlaps, the disturbed area. Thus, in its audibility and contracted sound-area, the Pendleton earth-shake differs from other shocks with a small disturbed area. Nor does it differ less in the nature of the sound, as will be seen from the next Table, in which the figures represent percentages of the total number of comparisons to the different types mentioned, for slight British earthquakes, the Pendleton earth-shake, and similar earth-shakes of small and approximately circular disturbed areas.

Sound-type.	Slight Earthquakes.	Pendleton Earth-shake.	Small Earth-shakes.
Passing waggons, etc.	31	14	...
Thunder	35	13	6
Wind	3	4	...
Loads of stones falling	8	9	12
Fall of heavy body ...	6	31	35
Explosions	14	29	47
Miscellaneous ...	4	...	...

The Pendleton earth-shake bears, indeed, a closer resemblance to the earthquakes which are characteristic of volcanic regions. For the sake of comparison, I reproduce in Fig. 2 the map of the isoseismal lines of the Etnean earthquake of August 8, 1894,[1] on half the scale of the map of the Pendleton shake. The curve marked A bounds the ruinous zone, in which buildings were destroyed and several persons killed. The curve B bounds the "very strong" zone, in which slight damage to buildings occurred; the curve C the "strong" zone, in which the shock was strong enough to make lamps, etc., swing; while, in the "slight" zone indicated by the curve D, the shock was just strong enough to be sensible.

In both cases it is clear, from the rapid decline in intensity, that the focus was situated at a very small depth. Secondly, in the Pendleton earth-shake, it follows, from the nature of the sound, that the focus was of larger dimensions than in the weak earth-shakes,

[1] M. Baratta, "Intorno ai recenti fenomeni endogeni avvenuti nella regione Etnea": Boll. della Soc. Geogr. Ital., Oct. 1894.

but smaller than in that of the slight, but true, earthquakes. Judging from the lengths of the axes of the inner isoseismal, it can hardly have been less than one mile, and may have been as much as one and a half miles, in length.

If the earth-shake were due to fault-slipping, the direction of the originating fault must be parallel or nearly so to that of the longer axes of the isoseismal lines, or about N. 37° W. to S. 37° E.; its hade being indeterminate, since each pair of isoseismal lines is separated by the same distance on both sides of the longer axes.[1]

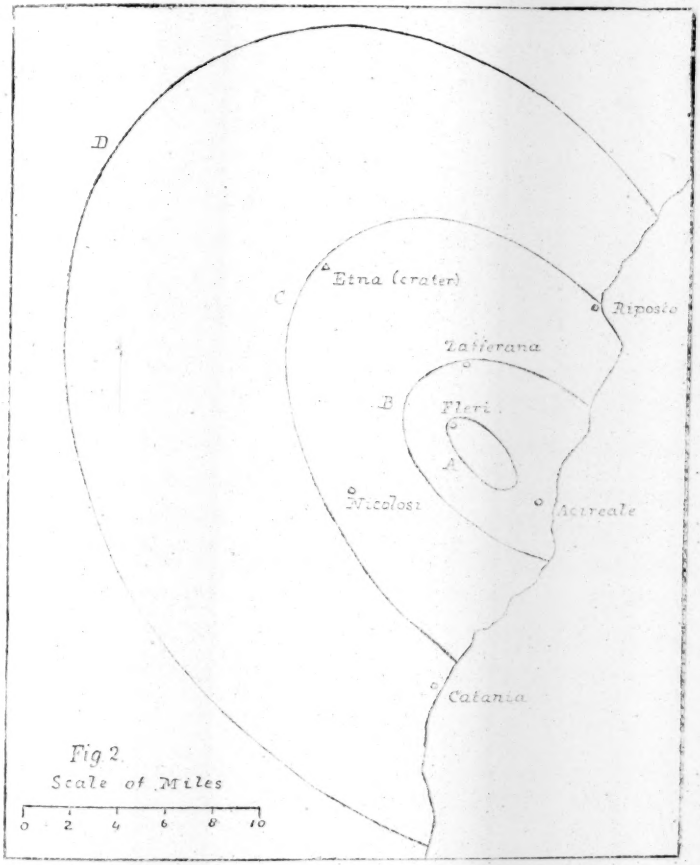


FIG. 2.—Isoseismal lines of Etnean Earthquake, Aug. 8th, 1894.

Now, in the neighbourhood of Pendleton, the mean direction of the Pendleton fault is from N. 34° W. to S. 34° E., and from its position, as indicated by the broken line on the map, we may,

[1] This would be the case if the vertical dimension of the focus was small.

I think, conclude that the earth-shake was due probably to a slip of this fault, but possibly to a subsidence along a band determined by, and closely adjoining, the fault. What the depth of the focus was we have no means of determining exactly, but it can hardly have been greater, and was probably much less, than a quarter of a mile, that is, considerably less than the depth of the present workings, which are from 800 to 1,100 yards below the surface.

That the shock was primarily due to work in connection with the mines there can, I think, be little doubt. The slip, whether along the fault or otherwise, can hardly have been precipitated directly by the withdrawal of the coal, but rather, as suggested to me by Mr. Joseph Dickinson, by the pumping of water in the overlying beds.[1] On this supposition, the slight depth of the focus, its great horizontal and small vertical dimensions, and the long interval that has elapsed since the working of the coal near the fault, would all receive a satisfactory explanation.

VI.—A Cordierite-bearing Lava from the Lake District.

By Alfred Harker, M.A., F.R.S.

ALTHOUGH the volcanic rocks of the English Lake District have received notice from time to time, any systematic account of them from the petrographical side has yet to be written. The most recent contribution, by the late Mr. E. E. Walker,[2] treated especially of the mode of occurrence of the garnet, which is so common a constituent, not only of the lavas and tuffs, but of the associated intrusive rocks, probably referable to the same Ordovician age. There can be no doubt that this mineral is sometimes a primary constituent, but very often a product of metamorphism. The object of the present note is to record the occurrence in one instance of a rarer mineral, which has not hitherto been observed in this series of rocks. Cordierite is found as a product of thermal metamorphism in the Coniston Flags near the Shap Granite,[3] and in the Skiddaw Slates of the Skiddaw granite area.[4] In the latter it is remarkably abundant and wide-spread.[5] The mineral is now found to occur, as an exceptional constituent, in the volcanic series.

The specimen was collected sixteen years ago on Sty Head Pass, just south of the watershed. As it does not, to the eye, present any unusual appearance, its occurrence was not more particularly noted. It comes then in the midst of the volcanic succession, between the principal group of basic lavas and the thick breccias and tuffs which build the central mountains of the district. Dr. Marr[6] has expressed the opinion that a large part of the garnetiferous rocks which occur

[1] For a similar suggestion see Geol. Mag., Dec. V, Vol. II (1905), p. 223.
[2] Quart. Journ. Geol. Soc., vol. lx (1904), pp. 70–104.
[3] Hutchings, Geol. Mag., 1894, pp. 65, 66.
[4] Harker, ibid., pp. 169, 170.
[5] Harker, *Naturalist*, 1906.
[6] Proc. Geol. Assoc., vol. xvi (1900), pp. 476, 477, and map, pl. xiii.

at or about this horizon are intrusive; but the rock in question has the characters of a lava, and those with which it is associated are apparently lavas and breccias. Most of these rocks on Sty Head Pass are more or less richly garnetiferous, but this specimen contains no garnet.

A thin slice (No. 1240 of the Sedgwick Museum collection) shows crystals of cordierite and felspar, with other minerals less abundant, in a fine-textured felspathic ground-mass. The cordierite crystals are about ·03 inch long and ·02 inch broad, and are invariably complex twins. A cross-section shows a hexagonal outline and, between crossed nicols, the well-known division into six fields, of which each opposite pair have like optical orientation. The mineral is partly fresh, partly converted into a finely divided scaly aggregate of a pale yellowish green colour, which may be identified with the usual 'pinite' alteration-product, probably a mixture of white mica and chlorite. The porphyritic felspars, giving rectangular sections ·02 to ·05 inch long, usually show twin-lamellæ, with the low extinction-angles of oligoclase. There are also untwinned crystals, which seem to be orthoclase. A few chloritic and ferruginous patches probably represent decayed augite, and there are occasional small crystals of magnetite and apatite. The ground-mass consists essentially of minute felspar rods with sensibly straight extinction. It thus appears that the rock has trachytic rather than andesitic characters, but it is not fresh enough for a very satisfactory diagnosis.

It is well known that cordierite occurs in some abundance in certain volcanic rocks, notably in andesites in the Eifel and the Cabo de Gata district. In such cases, even when the mode of occurrence of the mineral proves it to have crystallized from the igneous magma, there is evidence that the magma had been contaminated by dissolving non-igneous material.[1] A like origin may perhaps be suspected in the case of the cordierite (usually replaced by 'pinite') in some granites and quartz-porphyries, as in Cornwall, Brittany, and the Black Forest. Nevertheless, there is no obvious reason why cordierite should not occur exceptionally (as corundum undoubtedly does) as a normal constituent of igneous rocks. In the Sty Head lava there is nothing to suggest directly that the magma has enclosed and absorbed foreign material, and the rock occurs in the midst of a thick series of purely volcanic nature. Excepting the Skiddaw Slates at the base, which contain a few unimportant lava-flows, and the Coniston Limestone group at the top, with which the latest lavas are interbedded, the Lake District succession presents an unbroken sequence of volcanic rocks, with no trace of sedimentary material. Without expressing any opinion as to the origin of the cordierite, I leave the question in the hope that it may be elucidated by the discovery of other occurrences.

[1] For a discussion of this question see Teall, Proc. Geol. Assoc., vol. xvi (1899), pp. 61–74.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—February 16th, 1906.—J. E. Marr, Sc.D., F.R.S., President, in the Chair.

Annual General Meeting.

The Reports of the Council and of the Library and Museum Committee for the year 1905, proofs of which had been previously distributed to the Fellows, were read. This year again the Council announced a decrease in the number of Fellows, although the number elected was 48 (2 more than in 1904). Of these, 36 paid their admission fees before the end of the year, making, with 13 previously elected Fellows, a total accession of 49 in the course of the twelve months under review. During the same period, the losses by death, resignation, and removal amounted to 61 (8 more than in 1904), the actual decrease in the number of Fellows being, therefore, 12 (as compared with a decrease of 3 in 1904). The total number of Fellows on December 31st, 1905, was 1239.

The balance-sheet for that year showed receipts to the amount of £3,371 9*s.* 7*d.* (including a balance of £409 7*s.* 7*d.* brought forward from 1904), and an expenditure of £3,066 6*s.* 10*d.*

It was stated that increasingly rapid progress was being made with Mr. C. Davies Sherborn's manuscript Card-Catalogue of the Library, and that "the end was now in sight."

It was further stated that, Mr. Sherborn having intimated his inability to undertake, after the end of 1905, the preparation of the catalogue-slips for the International Catalogue of Scientific Literature, a Committee was appointed to review the part hitherto taken by the Society in furnishing the slips for British Geology to the Central Bureau, and that Committee had recommended the discontinuance of the work under present conditions. The Committee had also recommended that modifications be made in the Society's Record of Geological Literature, so as to include all geological literature published in Britain, and that slips from the aforesaid Record shall be available for the purposes of the Central Bureau of the International Catalogue of Scientific Literature.

It was announced that substantial progress had been made in the preparation of the forthcoming Centenary Record of the Society, initiated by Mr. Horace B. Woodward.

Reference was made to the lamented decease of Dr. W. T. Blanford, and to the steps taken to fill up the vacancies in the Treasurership and on the Council which his decease had created.

The list of Awards of the various Medals and Proceeds of Donation Funds in the gift of the Council was read.

The Report of the Library and Museum Committee enumerated the extensive additions made to the Society's Library, and gave some details as to the Card-Catalogue.

The Reports having been received, the President presented the Wollaston Medal to Dr. Henry Woodward, F.R.S., addressing him as follows:—

Dr. Woodward,—The Wollaston Medal, the highest honour which it is in the power of the Society to bestow, has been unanimously awarded to you by the Council in recognition of your researches concerning the mineral structure of the Earth, and particularly of your valuable contributions to the science of Palæontology, and more especially to our knowledge of the fossil Arthropoda.

There are many reasons why your fellow-workers and friends should rejoice at this award.

As Director of the Geological Department of the British Museum, your duties must have been heavy, but you have found time for an extraordinary amount of work in addition to that necessitated by your official position.

Many are the learned Societies which are indebted to you for counsel. Besides our own I may mention the Zoological, Palæontographical, Microscopical, and Malacological Societies, the Geologists' Association, and the Museums Association. Your labours on behalf of these Societies have been recognized by your having been called upon to occupy the Presidential Chair of the greater number of them.

The debt which geologists owe to you as Editor of the GEOLOGICAL MAGAZINE was admitted by Dr. Bonney, when, twenty years ago, on behalf of numerous subscribers he presented a testimonial to you in these apartments. That debt is now more than doubled, for you have been Editor of the Magazine for over forty years, and during the greater part of that period its chief Editor. In addition to this we are deeply grateful to you, and especially to her who has ever interested herself in your labours, for the "Index to the Geological Magazine" which appeared last year. It is a happy circumstance that the bestowal of this Medal upon you occurs in a month which witnesses the publication of the 500th number of that Magazine. Long may the Magazine continue to flourish in the hands of its present Editor!

Dr. Bonney, on the occasion to which I have alluded, paid a just tribute to your great kindness to other workers, and especially to the encouragement that you have ever given to the young. I gratefully remember the time when I, as an undergraduate, entered with feelings of trepidation the room of the Geological Department of the British Museum, then at Bloomsbury, how I was at once put at ease by you, and the help which I received. My experience has been that of many, and all who have benefited by your kindness will feel pleasure in the award of this Medal to you.

But although the services which I have mentioned are reasons for rejoicing at the award, they are merely subsidiary reasons for the bestowal of the Medal. The recipients of the Wollaston Medal have always qualified for it by increasing our knowledge of the mineral structure of the Earth by their own researches. It is unnecessary to say that you also have done this. Your contributions to the study of the palæontology of the Invertebrates, and especially of the fossil Arthropoda, are known to all workers, and need no further comment on my part.

I am glad that during the years of my occupation of this Chair the Wollaston Medal has been awarded to two British geologists, the one a distinguished petrologist, the other an eminent palæontologist.

Dr. Woodward, in reply, said:—

Mr. President,—It is now forty years ago (on February 16th, 1866) that I received from the President, Mr. William John Hamilton, at Somerset House, the award of the Balance of the Wollaston Donation Fund. I was then only a youth of 34 years of age, and little dreamed that I should be honoured by receiving at your hands to-day this Medal, the highest recognition that the Council can bestow.

I feel justified, however, in attributing this great honour quite as much to the personal friendship of the Council as to any merit of my own; but I am happy to find that this friendly disposition is also shared by a large body of the Fellows of the Society outside the Council, who have by letter and word of mouth expressed their kindly approval of the Council's choice.

I was elected a Fellow of this Society in 1864, and from 1867 until 1902 I have been (off and on) a Member of the Council (for a period of 35 years), and served also the office of President (1894–6), so that I naturally feel more deeply interested in the welfare of this Society than in any other, although I have been for many years, and am still, intimately associated with several other scientific bodies of kindred pursuits to our own.

You have alluded, Sir, in very favourable terms to my work, and I specially desire to thank you for your most kind reference to Mrs. Woodward's assistance in it, during all the years which are past, when we have worked side by side; but it would be incredible if, having had the grand opportunities afforded to me during forty-three years in the British Museum, I had not winnowed out some store of good grain as a contribution to the stock of palæontological knowledge in so long a life.

Whether as Editor of the Geological Magazine or in the Geological Department of the British Museum, my greatest aim and object in life has always been to be of assistance to others, and for this, I am glad to say, I have won the friendship and good-will of a very large circle of my fellow-workers, who have by their kindness rewarded me a hundredfold, as you, Sir, in the name of the Council have done to-day by the bestowal of this Medal, for which my grateful thanks are due.

The President then presented the Murchison Medal to Mr. Charles Thomas Clough, M.A., of H.M. Geological Survey, addressing him in the following words:—

Mr. Clough,—The Council have awarded the Murchison Medal to you, in recognition of your invaluable contributions to Geological Science by means of the maps and memoirs executed by you for H.M. Geological Survey.

Your detailed observations on the igneous and metamorphic rocks of Northern Britain have furnished geologists with most important material for the elucidation of many intricate problems. Your work is largely recorded in the various Memoirs of the Geological Survey. I may especially refer to those Memoirs which treat of the geology of the Cheviot Hills and of the Cowal District of Argyllshire, although your contributions to our science are also included in several other volumes of which you are one of the authors.

Your work is also recorded on the maps of those areas which you have surveyed. To produce those maps required, in addition to the ordinary accomplishments of a geological surveyor, petrographical and other knowledge of a very special kind, and they form a fitting monument to your skill. Their remarkable execution was recognized by the selection of certain of those of Ross-shire for exhibition at the St. Louis Exhibition, as examples of the maps on the 6 inch scale which are produced by the Geological Surveyors of this country.

Once again the Murchison Medal is awarded to a member of that Survey of which the founder was for so long chief. It is a source of gratification to me that, in the two years of my office as President, medals have been awarded to two old members of my own College, pupils of my College tutor, Dr. Bonney.

Mr. Clough replied as follows:—

Mr. President,—I thank the Council of the Geological Society very much for the honour that they have conferred upon me, and you, Sir, for the very kind words in which you have spoken of my work. I am conscious that this presentation is a matter not purely to myself—that it is another recognition by this Society of the value of the detailed co-operative work carried on by the Geological Survey—and it is to me a great additional pleasure to be thus tacitly associated in your minds with colleagues and friends with whom I have spent so many happy years. I have now been on the staff of the Geological Survey for more than thirty years, and I have seen that we sometimes get on the wrong track—that we have our 'downs' as well as our 'ups'—but we feel that, through all vicissitudes, a foundation of honest work is always appreciated by our brethren of the hammer.

It is a pleasure also on this occasion to acknowledge my personal indebtedness to my old friends and teachers of Cambridge days, and particularly to Professor Bonney and Professor Hughes. I feel indeed that I owe to others more than I can tell.

In handing the Lyell Medal, awarded to Professor Frank Dawson Adams, Ph.D., to Sir Archibald Geikie, Sc.D., Sec.R.S., for transmission to the recipient, the President addressed him as follows:—

Sir Archibald Geikie,—The Lyell Medal is awarded to Professor Frank D. Adams as a mark of honorary distinction, and as an expression on the part of the Council that he has deserved well of the science, particularly by his contributions to our knowledge of the Geology of Canada.

Professor Adams has been actively engaged in the study of the rocks of the great Dominion, and by work in the field and the laboratory has contributed largely to our knowledge of their petrography and their genesis. The study of those ancient rocks, the pre-Cambrian age of which was first demonstrated in Canada, has advanced far during recent years; but they are still to some degree enshrouded in mystery, and the labours of our Medallist are throwing light upon the obscurity.

He is also occupied with work among igneous rocks bearing upon problems connected with petrographical provinces and the differentiation of igneous magmas. I may more especially allude to his paper on "The Monteregian Hills—a Canadian Petrographical Province," published in the Journal of Geology for April–May, 1903.

Nor has he occupied himself with observation to the neglect of experiment, and one result of his laboratory work is that most interesting and suggestive paper, "An Experimental Investigation into the Flow of Marble," written in conjunction with Dr. J. T. Nicholson, and published in the Philosophical Transactions of the Royal Society (ser. A, vol. excv, p. 363). The experiments described in this paper tend to prove that not only

> "The solid earth on which we stand,
> In tracts of fluent heat began,
> And grew to seeming random forms,
> The seeming prey of cyclic storms,"

but that, even now, internal tracts which are in the ordinary sense solid,

> "flow
> From form to form,"

with results which have a most important effect upon various rock-structures.

Professor Adams is successful also as a teacher, and we rejoice to know that, under his care, a geological school flourishes in McGill University, endeared to us all by its association with the name of Sir William Dawson.

We regret Professor Adams's absence to-day. Let us hope that we may welcome him and many other geologists who are advancing our science in many parts of the Empire, on that auspicious occasion in the coming year when we shall celebrate the centenary of the foundation of our Society.

Sir Archibald Geikie, in reply, expressed the pleasure with which he received this Medal on behalf of his friend Professor Adams, from whom the following letter had just been received in answer to the Secretary's announcement of the award:—

"Petrographical Laboratory, McGill University, Montreal, February 2nd, 1906.

"Professor Edmund J. Garwood, M.A., Secretary of the Geological Society.

"Dear Sir,—

"I have received your kind letter conveying the very welcome and most unexpected information that the Council of the Geological Society have this year awarded to me the Lyell Medal. I regret extremely that it is impossible for me to be in London at the time of the annual meeting, so that I might have the pleasure of receiving the Medal in person.

"It is impossible for me to express adequately my thanks to the Council of the Geological Society for the great and unexpected honour which they have done me. Sir Charles Lyell's name, known as it is wherever geology is taught, is among us here associated with very kindly memories. For, during his second visit to America, Sir Charles met Dr. (afterwards Sir William) Dawson, then a young man commencing his geological work, and with him visited and studied the now renowned Joggins section of the Carboniferous of Nova Scotia. Lyell's help, counsel, and encouragement at that time, greatly stimulated Dawson to increased endeavour and further work. In 1881 Dawson became the recipient of the Lyell Medal, indicating that his endeavours had been crowned with some measure of success. As Sir William Dawson was my earliest teacher in geology, as well as my predecessor in the Chair which I now hold, the award of the Lyell Medal a second time to the Logan Professor of Geology at McGill University will still further serve to perpetuate Lyell's memory here, and to strengthen the bond of union between the geologists of Canada and the great Geological Society which has its seat at the Capital of the Empire.

"Please convey to the Council of the Society my sincere appreciation of the honour which they have done me, and accept my best thanks for the very kind words of your letter in which you conveyed the announcement of the gift.

"I remain, yours most sincerely,

"Frank D. Adams."

Professor Adams was still in the full vigour of life, and there was every reason to hope that his distinguished career would be prolonged for many years to come. That his geological activity shows no sign of slackening is proved by an intimation which the speaker had recently received from him, that he had completed the detailed investigation of a wide Archæan tract of Canada, and that the paper containing the account of this investigation might be expected in this country at an early date. His researches on the flow of rocks are also still in progress, and some further results on this interesting subject may be looked for before long. No more fitting recipient of this medal could have been selected than the geologist who carries on so ably the traditions of Logan and Dawson in Canada.

The President then presented the Prestwich Medal to Mr. William Whitaker, F.R.S., addressing him as follows:—

Mr. Whitaker,—The Prestwich Medal is awarded to you as an acknowledgment of the work that you have done for the advancement of geology, particularly by your researches among the Tertiary strata of the London and Hampshire Basins. Twenty years ago the Council awarded to you the Murchison Medal as an acknowledgment of your contributions to our science, which were particularized by the President of that day. Since then you have not been idle, and your recent work has been conducted on lines similar to those along which your earlier labours were carried on.

The Prestwich Medal is, however, doubtless awarded to you, not so much on account of what you have done since receiving the Murchison Medal, as in recognition of the value of your researches in those parts of our science which were advanced in a high degree by the founder of the medal which I am about to hand to you, namely, the study of the Tertiary and Quaternary deposits. The importance of your labours among the Tertiary deposits was aptly acknowledged by Dr. Bonney in 1886, in the following words:—

"Your papers on the western end of the London Basin, and on the Lower London Tertiaries of Kent, deserve to be ranked with the classic memoirs of Prestwich, as elucidating the geology of what I may call the Home District."

You have also followed in the footsteps of Prestwich in matters of economic geology. I may especially refer to the question of water-supply and to the study of underground geology, for which you, the recipient of the Medal, like its founder, have done so much.

In these circumstances, it must be a source of satisfaction to you as well as to your friends to find that the Council have added a new link connecting your name with that of Sir Joseph Prestwich.

Six years ago the honour fell to me of receiving a medal from your hands. It now falls to my lot to convey one to you, and it gives me much pleasure to hand it to a geologist with whom I have been on terms of friendship for thirty years.

Mr. Whitaker, in reply, said:—

Mr. President,—During the course of my official life on the Geological Survey it was my lot to work over ground that had been examined in detail by Prestwich, and the geology of which was described in the remarkable set of papers which he read to the Society.

In my work I was struck by the accuracy of observation and the judgment in inference shown by our past master in stratigraphy.

In another matter, too, I have had to follow along a line in which Prestwich was perhaps the pioneer, that is, the application of geology to questions of water-supply and kindred practical subjects.

It has been to me a constant pleasure to follow in the footsteps of one from whom I have learnt so much; and that, in the opinion of the Council, I have been a not unworthy follower, is evidenced by the award to me of the Medal that bears his honoured name.

I am proud, therefore, to-day in having my name again associated with that of one for whom I have always had a great regard, as a geologist and a friend.

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Dr. Finlay Lorimer Kitchin, M.A., the President addressed him in the following words:—

Dr. Kitchin,—The Balance of the Proceeds of the Wollaston Donation Fund is awarded to you as an acknowledgment of the value of your investigations on the Fossil Brachiopoda and other Invertebrata.

You took exceptional pains to fit yourself for your future calling by a prolonged course of study. After a successful career at Cambridge you proceeded to Munich, to study palæontology under a great master—the revered Zittel. The results of your training have been already shown by your various papers on Invertebrate Palæontology, among which I would specially allude to your work on the Jurassic Fauna of Cutch, published in the *Palæontologia Indica*.

In your present position your time, like that of most professional geologists, is no doubt largely occupied by routine work, but what you have already done encourages us to hope that your contributions to the science of palæontology will rank with those of your distinguished predecessors in the post which you now occupy.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Mr. Herbert Lapworth, B.Sc., addressing him as follows:—

Mr. Herbert Lapworth,—The Balance of the Proceeds of the Murchison Geological Fund is awarded to you in acknowledgment of your investigations among the Llandovery rocks of the Rhayader district.

During the intervals of a busy professional life you have devoted your attention to a line of research with which the name of Lapworth will ever be associated. The success of your investigations will be admitted by all who have read your admirable paper in the 56th volume of our Quarterly Journal. Of that paper I need merely say that it is worthy of the son of Charles Lapworth. We trust that our Journal will, in future years, contain many other equally valuable contributions from your pen.

I have much pleasure in handing to you this award, bestowed by the Council as an incentive to further work.

In presenting a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Mr. William George Fearnsides, M.A., the President addressed him as follows:—

Mr. Fearnsides,—A moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to you by the Council in recognition of your valuable contributions to our knowledge of the Lower Palæozoic and Cretaceous rocks.

Your first contribution to the Quarterly Journal recorded an interesting discovery on the borders of our University town, where one might have expected that little remained to be done. But, like so many Cambridge men, you, dissatisfied with the simplicity of the Mesozoic rocks of East Anglia, turned your attention to the older rocks of the western tracts of Britain; and that you have there already obtained most valuable results is proved by your admirable paper on "The Geology of Arenig Fawr and Moel Llytnant," published in last year's Quarterly Journal.

Your friends know that this is but a beginning, and that you have already done much work in Wales and elsewhere which is not yet published. We shall look forward with confidence to the results of your continued researches; and it gives me much pleasure to hand to you this proof of the Council's approbation of what you have already done, and of their interest in your future work.

The President then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Mr. Richard H. Solly, M.A., to Professor W. W. Watts, F.R.S., Sec.G.S., for transmission to the recipient, addressing him in the following words:—

Professor Watts,—The other moiety of the Lyell Geological Fund has been awarded to Mr. Richard H. Solly as an acknowledgment of the valuable work done by him on the minerals of the Binnenthal and elsewhere. Mr. Solly has carried out his labours under difficulties, and in some degree with a lack of encouragement which

would have disheartened many workers. Nevertheless he has steadily proceeded with his self-appointed task, and made substantial additions to his science. He is still engaged in his work on the Binnenthal, where he has discovered seven new minerals which he has described.

Will you express a hope to Mr. Solly that this award may act as an incentive to the prosecution of his researches, proving as it does that his work is appreciated by the Council of this Society?

In presenting a sum of twenty-five pounds from the Barlow-Jameson Fund to Mr. Henry C. Beasley, the President addressed him as follows:—

Mr. Beasley,—The sum of twenty-five pounds from the Barlow-Jameson Fund is awarded to you by the Council in recognition of your important work on the Triassic rocks. In connection with that work I may refer to your valuable descriptions of footprints from the Trias, in which you have abstained from burdening our fossil lists with new names. You have travelled much on either side of the Atlantic, obtaining thereby much useful information concerning geological matters, more especially with reference to the Triassic rocks.

I may also allude to your work on Glacial Geology, and to a suggestive paper on the water ejected from volcanoes.

I hope that this award of the Council will encourage you in the further prosecution of your fruitful researches.

The President then proceeded to read his Anniversary Address, giving first of all obituary notices of several Fellows deceased since the last annual meeting, including Dr. W. T. Blanford (elected a Fellow in 1860), Baron Ferdinand von Richthofen (el. For. Memb. 1888), Prof. G. Dewalque (el. For. Memb. 1880), Prof. F. V. Raulin (el. For. Corr. 1866), Mr. H. B. Medlicott (el. 1856), Capt. F. W. Hutton (el. 1860), Mr. J. Mansergh (el. 1876), Sir John B. Phear (el. 1852), Mr. W. J. Woodall (el. 1857), Mr. W. H. Goss (el. 1881), and Mr. T. Barron (el. 1896).

He then proceeded to describe "The Influence of the Geological Structure of English Lakeland upon its present Features.—A Study in Physiography."

After a brief account of the light thrown upon the structure of Lakeland by the writings of Otley, Hopkins, Clifton Ward, Goodchild, and Strahan, he considered his subject under the following heads:—

I. Events prior to the Uplift which produced the Dome.
II. Production of the Dome.
III. Initiation of the Drainage-lines.
IV. Effects of the three Types of Rocks upon the Scenery.
V. Modification of the old Drainage-lines.
VI. Depression of the Outskirts.
VII. Effects of Meteorological Conditions. (1) General.
VIII. ,, ,, ,, (2) The Glacial Period.
IX. Conclusion.

Of the events prior to the dome-shaped uplift he laid greatest stress upon the movements of Devonian times, which had caused the Lower Palæozoic rocks to be affected by a series of fractures forming a roughly rhomboidal network, the fissures being marked by belts of broken rock along their courses. These belts were spoken of as 'shatter-belts,' and their nature and distribution described.

He accepted Hopkins's view of the formation of a dome comparable in shape to a 'caddy-spoon' with the short handle to the

east, and argued that a subsidiary uplift occurred over the site of the Howgill Fells and adjoining country, and other subsidiary uplifts possibly over the Skiddaw and Helvellyn tracts. Between these uplifts and the Pennine Chain were the depressions of Edenside on the north-east, and of Morecambe Bay and the neighbouring lowlands on the south-east.

He gave further reasons in support of the view, previously put forward independently by Goodchild and himself, that the uplift of the dome and the final movements of the Pennine Chain were of Tertiary date.

After commenting on the now generally received view that rocks of New Red Sandstone age, and perhaps of later date, extended over the district, he discussed the nature of the radial drainage impressed upon these newer rocks during the uplift of the dome, and the removal of these rocks in the district itself by denudation, producing a superimposed drainage on the Lower Palæozoic rocks.

He then discussed the changes which took place in the valleys as the result of the imposition of the rivers upon the ancient rocks, and maintained that diversion of the river-courses had largely taken place owing to the easier erosion along the shatter-belts, describing in detail the cases of the Langdale, Duddon, and Borrowdale drainage areas in support of his views.

In this part of the address the position of the principal hanging-valleys was indicated, and it was pointed out that there were two sets, namely, those which 'mouthed' into valleys that had been deepened in softer rocks, and those which 'mouthed' into portions of main valleys that had been deepened along shatter-belts.

When discussing the effects of meteorological conditions he commented on hill-outlines, which he had elsewhere mentioned, where the upper parts of hill-slopes presented a convex outline towards west and south, and a concave curve towards east and north. This he attempted to explain as due to the more profuse growth of vegetation on the slopes facing west and south.

In discussing glacial changes, he admitted that in former papers he had over-estimated the importance of glacial dams in holding up the waters of lakes, and now recognized that Watendlath Tarn, Elterwater, and Thirlmere occurred in true rock-basins, and that other lakes of the district were therefore, in all probability, partly rock-basins.

He believed that some of his views would be proved capable of more than local application, and that they proved the importance of the study, on the part of the geographer, of geological details in addition to general geological structure.

The ballot for the Council and Officers was taken, and the following were declared duly elected for the ensuing year:—*Council:* H. H. Arnold-Bemrose, J.P., M.A.; Professor T. G. Bonney, Sc.D., LL.D., F.R.S., F.S.A.; Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S.; Professor E. J. Garwood, M.A.; Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec.R.S.; R. S. Herries, M.A.; F. L. Kitchin, M.A., Ph.D.; P. Lake, M.A.; G. W. Lamplugh, F.R.S.; R. Lydekker, B.A., F.R.S.; B. McNeill, Assoc.R.S.M.; J. E. Marr, Sc.D., F.R.S.; H. W. Monckton, Treas.L.S.; F. W. Rudler, I.S.O.; L. J. Spencer, M.A.; A. Strahan, M.A.,

F.R.S.; C. Fox Strangways; J. J. H. Teall, M.A., D.Sc., F.R.S.; R. H. Tiddeman, M.A.; Professor W. W. Watts, M.A., M.Sc., F.R.S.; Rev. H. H. Winwood, M.A.; A. S. Woodward, LL.D., F.R.S., F.L.S.; and H. B. Woodward, F.R.S.

Officers:—President: Sir Archibald Geikie, Sc.D., D.C.L., LL.D., Sec.R.S. *Vice-Presidents:* R. S. Herries, M.A.; J. E. Marr, Sc.D., F.R.S.; A. Strahan, M.A., F.R.S.; and J. J. H. Teall, M.A., D.Sc., F.R.S. *Secretaries:* Professor E. J. Garwood, M.A., and Professor W. W. Watts, M.A., M.Sc., F.R.S. *Foreign Secretary:* Sir John Evans, K.C.B., D.C.L., LL.D., F.R.S., F.L.S. *Treasurer:* H. W. Monckton, Treas.L.S.

II.—February 21st, 1906.—Sir Archibald Geikie, D.C.L., Sc.D., Sec. R.S., President, in the Chair. The following communications were read:—

1. "The Constitution of the Interior of the Earth, as revealed by Earthquakes." By Richard Dixon Oldham, F.G.S.

This paper is not devoted to a fresh theory of the earth, but is intended to set forth some of the information which can be obtained from the study of the records of distant earthquakes. The modern seismograph has given to geology a new instrument of research, and extended its scope much in the same way as the spectroscope extended the scope of astronomy, by enabling us to see into, and determine the physical constitution of, the interior of the earth at depths removed from any other possible means of research.

The distant record of a great earthquake exhibits three distinct phases, of which the third represents wave-motion which has travelled along the surface of the earth and is not dealt with in this paper, as it can give no information regarding the interior of the earth. The other two phases form the preliminary tremors, and it is shown that they represent the emergence of two distinct forms of wave-motion, which have been propagated through the earth.

A study of the intervals taken by these waves to reach remote points shows that, up to a distance of 120° of arc from the origin, they are propagated at a rate which increases with the depth of the wave-path, and reaches an average of over 10 km. sec. in the case of the first-phase, and over 6 km. sec. in the case of the second-phase waves. The increase, being gradual and continuous, may be attributed to the effect of increased pressure and temperature, and there is no indication of any change in physical constitution of the material traversed by waves which emerge at 120° or less from the origin.

Beyond this limit the first-phase waves show a reduction in the mean rate of transmission, while the second-phase waves are not to be found where they would be expected, but at about 11′ later. The interpretation is that the wave-paths emerging at these greater distances have entered a central core, in which the rate of transmission of the first-phase waves is reduced to about nine-tenths, and of the second-phase waves to about one-half, of the rate in the outer shell. The great reduction of rate in the case of the second-phase waves means great refraction, and the wave-paths which emerge at distances of over 130° from the origin must have reached their

emergence after passing on the farther side of the centre of the earth; the increase of length of wave-path means a longer interval between origin and emergence, and the sudden increase of interval at about 130° is explicable in this way. An alternative explanation is that the second-phase waves are extinguished at these distances, but this explanation is not regarded as probable by the author.

Either alternative leads to the conclusion that, after the outermost crust of the earth is passed, there is no indication of any material or rapid change of physical condition, nor probably of chemical composition, until a depth of about six-tenths of the radius is reached; but that below this there is a rapid passage to matter which has very different physical properties, if not also differing in chemical constitution. Without advancing any hypothesis as to the nature of this difference, the author points out that it will have to be reckoned with in any theory of the earth.

2. "The Tarannon Series of Tarannon." By Miss Ethel M. R. Wood, D.Sc. (Communicated by Professor Charles Lapworth, M.Sc., LL.D., F.R.S., F.G.S.)

A general historical review is given of the existing state of knowledge respecting the character and fossils of the strata included under the general title of 'Tarannon' on the maps of the Geological Survey in Wales. The Tarannon strata are most fully developed in the Llanbrynmair-Tarannon district, after which they are named; and the present paper gives the results of a detailed survey of the entire Tarannon Series as there exhibited. Various sections—typical and confirmatory—are described, showing the local sequence of the strata. Lists of the contained graptolites are given, and the species are paralleled with those from the corresponding beds of the South of Scotland, the Lake District, North Wales, Central Wales, and Sweden, demonstrating the similarity of the graptolitic succession in all these districts.

The authoress establishes the following local sequence:—

C. Wenlock Series.
- *Cb.* Fynyddog Group.
- *Ca.* Nant-ysgollon Group.
  - Zones of *Monograptus riccartonensis* and *Cyrtograptus Murchisoni*.

B. Tarannon Series.
- *Bd.* Dolgau Group. (Zone of *M. crenulatus*.)
- *Bc.* Talerddig Group. (Zone of *M. griestonensis*.)
- *Bb.* Gelli Group. (Zone of *M. crispus*.)
- *Ba.* Brynmair Group. (Zone of *M. turriculatus*.)

A. Llandovery Series.
- *Ac.* Twymyn Group.
  - Zone of *M. Sedgwickii*.
  - Zone of *Cephalograptus cometa*.
- *Ab.* Dolgadfan Group.
  - Zone of *M. convolutus*.
  - Zone of *M. fimbriatus*.
- *Aa.* Fachdre Group.
  - Zone of *Dimorphograptus Swanstoni*.

The Tarannon Series in this district has a maximum thickness of 3,500 feet, but thins somewhat as it is traced north-westward. It

rests conformably on Llandovery rocks below, and passes up without a break into Wenlock beds above. This rock-series is stratigraphically continuous from base to summit, and includes the four divisions of the Brynmair, Gelli, Talerddig, and Dolgau Groups, which, while they possess distinctive features of their own, are bound together by common palæontological characters. The lowest two, namely, the Brynmair and Gelli Groups, consist mainly of grey shales and mudstones with beds of thin flags, which increase in number and thickness as one ascends the sequence. The Talerddig Group is distinctly an arenaceous one, and contains numerous bands of thick grit which are generally massed together at four or five distinct horizons. The highest member of the series, the Dolgau Group, answering to the local 'Tarannon Shales' of the Geological Survey, consists of pale-grey and purple mudstones, the latter being inconstant in number and thickness in different parts of the district.

The strata of the overlying Wenlock Series present all the characters of the Denbigh Grits and Flags of North Wales. Some 2,000 feet are developed in this district, the upper beds consisting of grits and flags, while the lower are mainly shales and mudstones.

The Llandovery Series, which underlies the Tarannon Series, has, at present, been recognized only in the western part of the district, namely, in the valley of the Twymyn, and its rocks are brought to the surface by an anticlinal fold. Representatives of nearly the whole of the Llandovery beds have been met with at different localities, and five distinct graptolitic zones have been recognized. The rocks, which consist almost entirely of soft shales and mudstones, are probably not more than 400 feet thick.

A comparison of the graptolitic lists shows that the Tarannon Series, as here defined, corresponds almost exactly with the Gala or Queensberry Group of the South of Scotland, includes all the palæontological zones hitherto assigned to the Tarannon, and fills up the whole period intervening between the Llandovery below and the Wenlock above. It includes the extreme beds which have been mapped as Tarannon by the Geological Survey in Wales; and in the Tarannon District, at all events, the thickness of the series is equivalent to its maximum development elsewhere.

CORRESPONDENCE.

SMALL FOSSIL SHELLS PRESERVED WITHIN THE INTERIOR OF LARGER ONES AND IN THE BODY-CHAMBER OF CEPHALOPODS.

Sir,—It is a well-known fact to all collectors of fossils and practical geologists, that in the interior or body-cavity of larger fossils very often smaller ones may be found splendidly preserved, which otherwise are not to be got at all, or only in a very poor state, being crushed or weathered or wholly destroyed. In this way, when I worked, especially on the Tertiaries, I obtained the very

finest and rarest things by taking home with me portions of broken and badly damaged specimens of larger species and examining their contents at leisure. Very often, too, I found extremely fine and interesting fossils in the interior of Mesozoic and Palæozoic shells, in the moulds or casts of the living or body-chambers of Ammonites and other Cephalopoda, whose preceding chambers sometimes had completely disappeared. Dr. Krause described a complete specimen of a crab, *Glyphæa leionoton*, found in the living chamber of an *Ammonites gigas* from our Portland Beds (Zeitschrift Deutsch. Geol. Ges., xliii, p. 194, pl. x, fig. 1), and I got only last summer a very fine complete specimen of *Æger*, n.sp. (?), with the antennæ preserved, in the living chamber of a large *Stephanoceras* from our Middle Jurassic beds. I therefore cannot agree with the view expressed in the English edition of Zittel's Textbook of Palæontology (translated and edited by C. R. Eastman, p. 658), that "some of these bodies (viz., *Cardiocaris*, *Pholadocaris*, and *Spathiocaris*), which have been found in the living chamber of *Goniatites* (*G. intumescens*), *have undoubtedly served as opercula or aptychi of these Cephalopods.*" I may add that they are not commonly found there, and if there, as usual together with specimens of *Orthoceras*, *Cardiola*, small *Goniatites*, *Entomis*, and other fossils, certainly have nothing to do with the organisation of *Goniatites intumescens*, but only happen to occur associated with it in the same rock.

A. von Koenen.

Royal Geological Museum and
University of Göttingen, Germany.

OBITUARY.

JOHN GEORGE GOODCHILD, F.G.S.

Born May 26, 1844. Died February 21, 1906.

It is with much regret we have to record the death of a valued member of the Geological Survey of Scotland, who for some years had filled the office of Curator of the Geological Survey Collections in the Royal Scottish Museum, and who died in Edinburgh on the 21st February after a lingering illness. Born near London on 26th May, 1844, he joined the Geological Survey in 1867, and for many years was engaged in mapping areas in the north of England, particularly in the neighbourhood of the Lake District. Thereafter he was removed to the Survey Office in Jermyn Street, London, and in 1887 was transferred to Scotland, where he was placed in charge of the collections obtained by the Scottish staff, and deposited in the Royal Scottish Museum, an appointment for which he was specially adapted. In recent years he had charge of the Scottish Mineral Collection in the same museum, which led him to devote a large amount of time to the special study of mineralogy. Gifted with remarkable fluency and lucidity of exposition, he became widely known as a successful lecturer on geology. During 1884, 1885, and 1886, he gave courses of lectures on physical geography, geology,

and palæontology at Toynbee Hall, and since he settled in Edinburgh he had lectured on these subjects at the Heriot-Watt College and other institutions. Possessing remarkable powers of receptivity, a mind extremely susceptible of new ideas, and a facile pen, he contributed a very large number of papers—about 200—on a wide range of subjects to the Proceedings of various scientific societies in England and Scotland, and no fewer than 24 to the pages of the Geological Magazine (1874–1902). He also edited the important work in two volumes on Scottish Mineralogy, by the late Professor Heddle, published after Prof. Heddle's death. In recognition of his labours he was awarded, in 1874, the Wollaston Fund by the Geological Society of London. His versatile gifts were further shown by his keen interest in other branches of science, his knowledge of botany and ornithology being considerable. All these varied qualifications made him a valuable conductor of field-excursions, and an exponent of geological problems among numerous scientific societies. His restless mental and bodily energy, reacting on a constitution never very robust, may be said to have shortened his career. He leaves a widow and three sons, the eldest of whom graduated with honours at Cambridge, and is now Principal of the Technical College at Wandsworth, London; the second is a magazine artist, and the third recently graduated in medicine at Edinburgh University.

At a meeting of the Edinburgh Geological Society on Feb. 21st, Mr. James Currie, F.R.S.E., the President, moved, and Dr. J. Horne, F.R.S., seconded, the following resolution, which was at once carried:—"That the Edinburgh Geological Society desires to place on record their appreciation of the valuable work done by the late Mr. Goodchild in the sphere of general geology, and more especially in the elucidation of problems connected with Scottish geology and mineralogy, and expresses its sincere sympathy with his widow and family."—*The Scotsman*, February 22nd, 1906.

THOMAS BARRON, A.R.C.S., F.G.S.

Born 1867. Died January 30, 1906.

Thomas Barron was educated at Greenlaw public school, Berwickshire, and afterwards attended the Science and Art Classes at Hume. He gained a medal with first-class honours and a scholarship in the Normal School of Science (as it was then called) at South Kensington. In that school he continued his studies; he was elected an Associate of the Royal College of Science, and eventually he became Assistant Demonstrator to Professor Judd.

In 1896 he communicated to the Geological Magazine a paper "On a new British Rock containing Nepheline and Riebeckite."

He was subsequently appointed to a post on the Geological Survey of Egypt, and there he laboured with signal success.

In 1901, with Dr. W. F. Hume, he contributed to the Geological Magazine "Notes on the Geology of the Eastern Desert of Egypt,"

and in 1903 was issued the full Report of the Geological Survey (dated 1902) on the "Topography and Geology of the Eastern Desert of Egypt," with maps, plates, and sections. His services were called for on questions of irrigation, in the survey of the peninsula of Sinai, and in an exploration for coal in Abyssinia. In 1904 he conducted an expedition in the Soudan with the object of finding water, and in the following year he became Geological Surveyor to the Soudan Government.

He died of enteric fever at El Koweit, Suakim, on the 30th of January, aged 39.

WILLIAM CUNNINGTON, F.G.S.

Born 1813. Died February, 1906.

The death, in his ninety-third year, of William Cunnington removes one of the more distinguished local geologists and antiquaries whose observations and collections have done much to advance science. During the middle portion of last century the name of William Cunnington, of Devizes, became familiar to geologists. His extensive collection of the Cretaceous fossils of Wiltshire furnished materials which aided Davidson in his Monograph on Cretaceous Brachiopoda, Wright in his Cretaceous Echinodermata, and Daniel Sharpe in his Cretaceous Cephalopoda; and in the last-mentioned work *Ammonites Cunningtoni*, from the Lower Chalk near Devizes, was named in his honour. For many years Cunnington was one of the honorary secretaries of the Palæontographical Society. He was elected a Fellow of the Geological Society in 1854. He obtained a fine series of sponges from the Upper Greensand of Warminster, and many of these are described or mentioned in Dr. G. J. Hinde's "Catalogue of the Fossil Sponges in the Geological Department of the British Museum."

He was a grandson of William Cunnington, F.S.A., of Heytesbury in Wiltshire, who was interested in geological pursuits, probably through acquaintance with William Smith, and celebrated for his antiquarian researches in the county, in which he was associated with Sir Richard Colt Hoare. While a lad he began to collect fossils from the chalk-pits of Upavon, and subsequently, when he had settled at Devizes as a wine merchant, he assiduously studied the local geology—especially the strata from the Great Oolite Series to the Portland Beds, the Lower Greensand, the Gault, Upper Greensand, and Chalk; and he ultimately amassed a collection of more than 20,000 fossils. He was one of the founders of the Devizes Museum, and was honorary curator from the time of its opening in 1853.

One of his earliest papers was "On the Fossil Cephalopoda from the Oxford Clay constituting the genus *Belemnoteuthis* (Pearce)," *London Geol. Journ.*, No. 3, 1847, p. 1. Most of his contributions to geological literature were, however, published in the Magazine of the Wiltshire Archæological and Natural History Society; they included